# III. Summary of Operations, Impacts, and Pollution Prevention Opportunities for the Agricultural Production Industries: Crops, Greenhouses/Nurseries, and Forestry

This section provides an overview of commonly employed operations and maintenance activities in the agricultural production industries of crops, greenhouses/nurseries, and forestry. This discussion is not exhaustive; the operations and maintenance activities discussed are intended to represent the material inputs, major pollution outputs, and associated environmental impacts from these agricultural production practices. General pollution prevention and waste minimization opportunities are also discussed in the context of each of the operations and maintenance activities.

The choice of practices or operations influences the material used and the resulting pollution outputs and environmental impacts. Keep in mind that environmental impacts are relative, as some kinds of pollution outputs have far greater impacts than others.

### *Impact of Agriculture on the Environment*

> The Clean Water Act Plan of 1998 called for the development of the EPA/USDA Unified National Strategy for AFOs to minimize the water quality and public health impacts of AFOs.

According to the *EPA/USDA Unified National Strategy for Animal Feeding Operations* (March 9, 1999), despite progress in improving water quality, 40 percent of the Nation's waterways assessed by States do not meet goals for fishing, swimming, or both. While pollution from factories and sewage treatment plants has been dramatically reduced, the runoff from city streets, agricultural activities, including AFOs, and other sources continues to degrade the environment and puts environmental resources (i.e., surface water, drinking water) at risk. According to EPA's 1996 305(b) water quality report, the top two pollutants from agriculture were identified as sediment and nutrients, respectively. Additional agricultural pollutants, such as animal wastes, salts, and pesticides, were identified by EPA[1]. The following presents a brief discussion of the environmental impacts or effects of agricultural pollutants.

(1) ***Nutrients***. Excess nutrients in water (i.e., phosphorus and nitrogen) can result in or contribute to low levels of dissolved oxygen (anoxia), eutrophication, and toxic algal blooms. These conditions may be

[1] *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, U.S. Environmental Protection Agency, January 1993.

harmful to human health and ecosystems; may adversely affect the suitability of the water for other uses; and, in combination with other circumstances, have been associated with outbreaks of microbes such as *Pfiesteria piscicida*.

- Phosphorus. Phosphorus determines the amount of algae growth and aging that occurs in freshwater bodies. Runoff and erosion can carry some of the applied phosphorus to nearby water bodies.

- Nitrogen. In addition to eutrophication, excessive nitrogen causes other water quality problems. Dissolved ammonia at concentrations above 0.2 mg/L may be toxic to fish. Biologically important inorganic forms of nitrogen are ammonium, nitrate, and nitrite. Ammonium becomes adsorbed to the soil and is lost primarily with eroding sediment. Even if nitrogen is not in a readily available form as it leaves the field, it can be converted to an available form either during transport or after delivery to water bodies. Nitrogen in the form of nitrate, can contaminate drinking water supplies drawn from groundwater. Nitrates above 10 ppm in drinking water are potentially dangerous, especially to newborn infants.

(2) ***Sediment.*** Sediment affects the use of water in many ways. Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, clog the filtering capacity of filter feeders, and clog and harm the gills of fish. Turbidity interferes with the feeding habits of fish. These effects combine to reduce fish and plant populations and decrease the overall productivity of waters. In addition, recreation is limited because of the decreased fish population and the water's unappealing, turbid appearance. Turbidity also reduces visibility, making swimming less safe.

(3) ***Animal Wastes***. Animal waste includes the fecal and urinary wastes of livestock and poultry; process water (such as from a milking parlor); and the feed, bedding, litter, and soil with which fecal and urinary matter and process water become intermixed. Manure and wastewater from animal feeding operations have the potential to contribute pollutants such as nutrients (e.g., nitrogen and phosphorus), organic matter, sediments, pathogens, heavy metals, hormones, antibiotics, and ammonia to the environment. Decomposing organic matter (i.e., animal waste) can reduce oxygen levels and cause fish kills. Solids deposited in waterbodies can accelerate eutrophication through the release of nutrients over extended periods of time.

Contamination of groundwater can be a problem if runoff results from the misapplication or over application of manure to land or if storage structures are not built to minimize seepage. Because animal feed sometimes contains heavy metals (e.g., arsenic, copper, zinc), the possibility for harmful accumulations of metals on land where manure is improperly or over applied is possible.

(4) ***Salts***. Salts are a product of the natural weathering process of soil and geologic material. In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs. The accumulation of soluble and exchangeable salts (i.e., metal compounds in the soil that can chemically change) leads to soil dispersion (i.e., movement of soil in air and water), structure breakdown, decreased infiltration, and possible toxicity; thus, salts often become a serious problem on irrigated land, both for continued agricultural production and for water quality considerations. High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops.

(5) ***Pesticides.*** The primary pollutants from pesticides are the active and inert ingredients, diluents, and any persistent degradation products. Pesticides and their degradation products may enter groundwater and surface water in solution, in emulsion, or bound to soils. Pesticides may, in some instances, cause impairments to the uses of surface waters and groundwater. Both the degradation and sorption characteristics of pesticides are highly variable. Some types of pesticides are resistant to degradation and may persist and/or accumulate in aquatic ecosystems. Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species.

At a crop production establishment, pesticides may be applied directly to crops or to structures (e.g., barns, housing units) to control pests, including parasites, vectors (i.e., an organism, such as a mosquito or tick, that carries disease-causing microorganisms from one host to another), and predators. Potential contamination from pesticides is generally greatest when rainfall is intense and occurs shortly after pesticide application, a condition during which water runoff and soil losses are also greatest. Pesticides can be transported to receiving waters either in dissolved form or attached to soil. Dissolved pesticides may be leached into groundwater supplies.

People, wildlife, and the environment can also be exposed to pesticide residues in the form of spray drift. Spray drift is the physical movement of a pesticide through air at the time of application or soon thereafter, to any site other than that intended for application. A number of factors influence spray drift including weather conditions, topography, the crop or area being sprayed, and application equipment and methods.

Pesticides are both suspected and known for causing immediate and delayed-onset health hazards for humans. If exposed to pesticides, humans may experience adverse effects, such as nausea, respiratory distress, or more severe symptoms up to and including death. Animals and birds impacted by pesticides can experience similar illnesses or develop other types of physical distress.

***Pollution Prevention/Waste Minimization Opportunities in Crop Production, Greenhouses/Nurseries, and Forestry***

The best way to reduce pollution is to prevent it in the first place. Industries have creatively implemented pollution prevention techniques that improve operations and increase profits while minimizing environmental impacts. This can be done in many ways such as reducing material inputs, reusing byproducts, improving management practices, and employing substitute toxic chemicals.

To encourage these approaches, this section provides general descriptions of some pollution prevention advances that have been implemented within the agricultural production industries for crops, greenhouses/nurseries, and forestry. While the list is not exhaustive, it does provide core information that can be used as the starting point for establishments interested in beginning their own pollution prevention projects. This section provides information from real activities that may be or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land, and water pollutant releases.

The use of pollution prevention technologies and environmental controls can substantially reduce the volume and concentration of the contaminants released/discharged into the surrounding environment. In some cases, these pollution prevention approaches may be economically beneficial to the agricultural production industries because they decrease the amount of chemicals needed, and therefore the cost of maintaining operations.

Waste minimization generally encompasses any source reduction or recycling that results in either the reduction of total volume or the toxicity of hazardous waste. Source reduction is a reduction of waste generation at the source, usually within a process. Source reduction can include process modifications, feedstock (raw material) substitution, housekeeping and management processes, and increases in efficiency of machinery and equipment. Source reduction includes any activity that reduces the amount of waste that exits a process. Recycling refers to the use or reuse of a waste as an effective substitute for a commercial product or as an ingredient or feedstock in an industrial process.

It should be noted that as individual practices, these pollution prevention and waste minimization practices can significantly reduce the environmental impacts of agricultural operations. However, to get the full effect of the practices and maximize pollution prevention potential, an agricultural operation must consider its individual practices in the context of a system. The practices, ranging from preparing the soil for planting to harvest and post-harvest activities, combine to form an integrated system in which each practice interacts with the others and is affected by the others. That is, outputs from one practice may be inputs into one of the other practices, in effect creating a closed-loop system that both maximizes profits and minimizes environmental impacts. By considering their establishments as systems, operators will be better able to evaluate and implement pollution prevention or waste minimization opportunities.

## III.A. Crop Production: Operations, Impacts, and Pollution Prevention Opportunities

The production of crops generally includes the following activities:

- Preparing the site/soil for crops
- Planting/tending crops
- Applying and storing nutrients
- Pest control
- Irrigating crops
- Harvesting crops and post-harvesting activities
- Crop field residue destruction
- Maintaining equipment and vehicles
- Fuel use and fueling activities
- Maintaining the site.

The additional activities of planning and management are required for all of the above processes to occur. Exhibit 20 presents the raw material inputs and pollution outputs from each of these processes.

| Exhibit 20. Crop Production Activities, Raw Material Inputs, and Potential Pollution Outputs | | |
|---|---|---|
| **Activity** | **Raw Material Input** | **Potential Pollution Output** |
| Preparing the site/soil, including tilling, drainage and erosion control structures, and adjusting soil pH | • Mulch, seeds, and water<br>• Alkaline material<br>• Water | • Air emissions (e.g., smoke and dust)<br>• Sediment, nutrient and pesticide runoff from soil erosion<br>• Spilled material or excessively applied material |
| Planting/tending | • Seed, seedlings | • Air emissions (e.g., dust, emissions from planting equipment)<br>• Sediment, nutrient, pesticide runoff from soil erosion<br>• Plants, branches, leaves, etc. |
| Applying and storing nutrients (e.g., fertilizers, manure, biosolids) | • Organic nutrients<br>• Chemicals<br>• Water | • Runoff and leaching of unused or misapplied nutrients<br>• Chemical air emissions<br>• Odor |
| Applying pesticides and pest control | • Pesticides (including insecticides, rodenticides, fungicides, and herbicides) | • Runoff and leaching of unused or misapplied pesticides<br>• Chemical air emissions |
| Irrigating (not including nutrient application) | • Water<br>• Chemicals | • Air emissions<br>• Potential runoff and leaching of materials (e.g., manure, chemicals, pesticides) from saturated areas |
| Harvesting/post-harvesting activities, including harvesting; washing, processing, packaging, loading, and transporting products; and destroying crop residue | • Water<br>• Corrugated cardboard<br>• Paper<br>• Plastic and fabric packaging materials | • Unusable or spilled products<br>• Worker exposure to pesticides<br>• Organic- and pesticide-contaminated wastewater<br>• Discarded packaging materials |

| Exhibit 20. Crop Production Activities, Raw Material Inputs, and Potential Pollution Outputs | | |
|---|---|---|
| **Activity** | **Raw Material Input** | **Potential Pollution Output** |
| Maintaining and repairing agricultural machinery and vehicles | S Oil<br>S Lubricating fluid<br>S Fuel<br>S Coolants<br>S Solvents<br>S Tires<br>S Batteries<br>S Equipment parts | S Used oil<br>S Spent fluids<br>S Spent batteries<br>S Metal machining wastes<br>S Spent organic solvents<br>S Tires<br>S Air, surface water, and soil pollution resulting from spills and/or releases of fluids<br>S Groundwater pollution resulting from spills or releases of fluids and discharges to Class V wells |
| Fuel use and fueling activities | S Fuel | S Air emissions from machinery<br>S Air, water, soil, and groundwater pollution resulting from spills |
| Maintaining the site: | | |
| (1) Providing water, including drinking water and water used for personal hygiene | S Water | S Contaminated water supply |
| (2) Managing PCBs (i.e., PCBs in generators and equipment) | S PCB-containing oils and equipment | S Spills or releases of PCBs |
| (3) Renovation/demolition | S Asbestos<br>S Lead | S Airborne asbestos fibers<br>S Lead-based paint, dust, and chips<br>S Soil contamination |

## III.A.1. Preparing the Site/Soil for Crops

Prior to planting crops, the site/soil must be prepared. Site/soil preparation can involve tilling the soil or chemical cultivation, building drainage and erosion control structures, and adjusting soil pH.

### Preparing the Soil by Tilling or Chemical Cultivation

Tilling aerates the soil, allows seeds/seedlings to be placed in the soil, and helps roots take hold of the soil. It also improves drainage and allows for better assimilation of nutrients and pesticides into the soil. Tillage methods generally consist of intensive/conventional, reduced tillage, and conservation tillage. The difference in the tillage methods is the amount of soil disturbed and the amount of crop residue allowed to remain during the current planting.

- Intensive/conventional tillage is sometimes conducted in two phases – primary tillage with a moldboard plow followed by secondary tillage with a power tiller or disc harrow. Intensive/conventional tillage can range from complete tillage of the entire field to tillage that allows 15 percent of the crop residue to remain.

- Reduced tillage consists of disturbing from 15 to 30 percent of the soil and crop residue.

- Conservation tillage methods are designed to reduce the loss of soil erosion caused by wind and water. Conservation tillage methods allow 30 percent or more of the soil and crop residue to remain undisturbed and thus reduce soil erosion by water and/or maintain at least 1,000 pounds per acre of flat, small grain residue to reduce soil erosion by wind. Common conservation tillage methods are no-till, strip-till, ridge-till, and mulch till.

    - No-till has minimal soil disturbance since the seed is planted with essentially no tillage of the soil and no disturbance of the crop residue.

    - Strip-till involves tillage of a narrow strip of soil and planting of the seed or seedling in that tilled area.

    - Ridge-till methods disturb a narrow strip of soil that was created during previous cultivation. The crop is planted on the ridge and the crop residue remains between each ridge.

    - Mulch-till involves disturbing the entire soil surface and then applying a crop protection product and/or cultivation[2].

In addition to tilling, soil may be prepared for planting by chemical cultivation. Chemical cultivation includes the application of a systematic herbicide to kill weeds and grasses.

[2] 1998 Crop Residual Management Survey Executive Summary, Top 10 Conservation Tillage Benefits, Conservation Tillage Information Center.

***Potential Pollution Outputs and Environmental Impacts***

The primary pollution output from preparing soil for planting is soil erosion. Erosion can reduce the productivity of the soil and increase the need for additional fertilizer and other inputs. Sediments and other pollutants (e.g., nutrients, pesticides) that are transported offsite may eventually enter surface waters, settle out, and cause degradation of the water quality. When it settles, the sediments fill interstitial spaces in lake bottoms or streambeds. They can eliminate essential habitat, cover food sources and spawning sites, smother bottom-dwelling organisms, and be detrimental to many species of fish. Sediment deposition also reduces the capacity of stream channels to carry water and of reservoirs to hold water. This decreased flow and storage capacity can lead to increased flooding and decreased water supplies.

Sediments can also be suspended in surface waters which causes increased water turbidity. Water turbidity limits the depth to which light can penetrate and adversely affecting aquatic vegetation photosynthesis. Suspended sediments can also damage the gills of some fish species, causing them to suffocate. Turbid waters tend to have higher temperatures and lower dissolved oxygen concentrations. Decreased dissolved oxygen levels can kill aquatic vegetation, fish, and benthic invertebrates.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention opportunities arise from the use of reduced or conservation tillage methods, which reduce soil erosion and maintain the existing soil structure (the way the soil particles clump together into larger, almost crystalline, units). Advantages of conservation tillage include:

- T Greater water retention/reduced water usage and energy used for pumping (by increasing the water retention capacity of irrigated soils, there may be opportunities to lengthen periods between irrigation events, thereby saving energy that would otherwise have been used for pumping irrigation water).

- T Reduced erosion of sediment and runoff of nutrients.

- T Reduced fuel use due to reduced equipment use.

- T Reduced wind erosion resulting in less dust.

- Shading which reduces weed growth and subsequent herbicide use. The effectiveness of shading is dependent on the type of crop and distance between plants.

- Prevention of the growth of some molds that have a much lower overwinter survival if not incorporated into the soil.

- Crop residues left undisturbed provide habitats for many beneficial insects and spiders that help control crop predators (e.g., cereal leaf beetle), thereby reducing the need for insecticides. In addition, crop residues help speed the decomposition process and aid plant nutrient cycling.

One possible disadvantage of conservation tillage methods is the carryover of pests (e.g., weeds, diseases, and some insects) in the crop residue. This may result in a subsequent increased use of pesticides and increased level of pesticides in runoff.

**Building Drainage and Erosion Control Structures**

Erosion control practices are necessary for agricultural operations to control runoff and reduce the amount of soil erosion caused by that runoff. In areas with good drainage, crops are better able to use nutrients and chemicals and will benefit from these optimum growing conditions. When building erosion control structures, newly-graded soil surfaces may be stabilized with mulch prior to the establishment of a vegetative cover.

To establish good drainage, one or a combination of drainage and erosion control structures can be built and used depending on the site characteristics (e.g., slope, crop type, or climate). These structures include:

- *Diversions.* Diversions are vegetated channels across the slope that intercept surface runoff and redirect it along a gradient to a controlled outlet. Diversions can reduce the amount of soil/sediment and related pollutants delivered to surface waters.

- *Grassed waterways*. Grassed waterways, which are shaped or graded to specified dimensions, are used for the stable conveyance of runoff. Grassed waterways can reduce soil erosion in areas, such as gullies or ephemeral gullies, with concentrated flows.

- *Water and sediment control basins.* Water and sediment control basins are constructed to collect and store debris or sediment. They detain runoff, allowing the sediment to settle out in the basin before the water is discharged to a waterway.

- *Filter strips*. Filter strips are vegetated areas that are used to trap sediment, organic matter, and other pollutants that are carried in runoff. While filter strips require frequent maintenance and have relatively short service lives, they are generally effective in removing pollutants when a shallow sheet flow is passed through the vegetated areas.

- *Riparian buffers*. Herbaceous or forest riparian buffers are areas of grasses, shrubs, or trees placed upgrade from waterways and water bodies. These buffers prevent or minimize damage to surface waters by containing eroded sediment, chemicals, nutrients, and organics. In addition, buffers reduce the amount of these pollutants that leach into shallow groundwater.

- *Terracing and contouring*. Terracing and contouring are practices that both use sloped surfaces to reduce or control soil erosion. Terracing involves shaping an area so that it is sloped, and contouring involves moving soil in an area so that it is sloped.

- *Drainage tiles*. Surface and subsurface drainage tiles are often used to remove standing water from fields and direct them to more structured erosion control measures.

***Potential Pollution Outputs and Environmental Impacts***
As described above for tilling, soil erosion and its impact to surface waters is a significant environmental concern and the primary pollution from building drainage structures. Wetlands, the interface between terrestrial and aquatic systems, are particularly susceptible to impacts from runoff and soil erosion. Such impacts include damage to watershed hydrology and water quality, and the habitat for many animal and plant species.

***Pollution Prevention/Waste Minimization Opportunities***
The primary pollution prevention opportunities of drainage and erosion control structures are the minimization of soil erosion and the reduction of runoff which transports nutrients, sediments, and pesticides to the environment.

> Preventing or controlling erosion is based on two main concepts: (1) disturb the smallest area of land possible for the shortest period of time, and (2) stabilize the disturbed soils to prevent erosion from occurring.

Drainage and erosion controls can reduce the amount of sediment that is transported offsite in runoff. Any of the drainage and erosion control structures described above can be used to reduce soil erosion and transport. Additional examples of erosion control structures or activities include: field borders; grade stabilization structures; sediment retention ponds; reestablished wetlands; immediate seeding, mulch/mats, and sodding to stabilize exposed soil surfaces; wind erosion controls; and scheduled grading and shaping (e.g., construction of diversions) during dry weather.

**Adjusting the Soil pH**

Adjusting the soil pH helps ensure the soil contains the proper characteristics to maximize crop production. Many crop producers add materials to soil to achieve a soil pH that maximizes crop production. Typically, alkaline materials, such as lime, lime sulfur, caustic soda, caustic potash, soda ash, magnesia, and dolomitic lime, are added to increase the pH in acidic soils.

***Potential Pollution Outputs and Environmental Impacts***
The adjustment of soil pH typically results in little to no pollution outputs and generally has little to no environmental impacts. However, impacts to surface waters could occur if spilled or misapplied alkaline materials are carried in runoff.

***Pollution Prevention/Waste Minimization Opportunities***
The primary pollution prevention opportunities for this activity include properly storing the materials used to adjust pH to minimize spills, and applying these materials in a manner that minimizes runoff.

## III.A.2. Planting/Tending Crops

Planting involves the placement of seeds or seedlings into the soil. This activity can be conducted either by hand (in small operations) or mechanically. Tending the product involves any post-planting activities designed to maximize crop production at harvest. Tending may involve hand labor (e.g., hoeing or pruning) or machine labor.

***Potential Pollution Outputs and Environmental Impacts***

Pollution outputs from planting crops include air emissions, particularly dust, and wastes such as seed bags. The planting process is often combined with other operations, such as tilling or fertilizer/pesticide application, which can pollute surface waters and groundwater from runoff and leaching, respectively. Tending activities that disturb the soil may result in soil erosion, the impacts of which are similar to those previously discussed under tilling. Tending may also produce wastes (e.g., plant branches or other parts).

***Pollution Prevention/Waste Minimization Opportunities***

Air emissions from planting activities can be minimized by properly maintaining farm machinery. Sections III.A.7 details how to operate and maintain farm vehicles and machinery in an environmentally responsible manner.

By buying seeds in greater bulk, farms can reduce the volume of seed bags that must be disposed of. Also, certain innovative methods of collecting and dispersing seeds are now available that eliminate the need for bags.

### III.A.3. Applying Nutrients to Crops

During various phases of crop production, nutrients such as nitrogen, phosphorus, potassium, and other nutrients are applied to crops to enhance crop growth. Nutrient use has been encouraged by the adoption of high-yielding seeds that are more responsive to nutrient application. Therefore, nearly all acres planted with crops are treated with one or more sources of nutrients, such as fertilizers, manure, and/or biosolids.

Nutrients are applied directly to plants or the soil surface, incorporated or injected into the soil, or applied with irrigation water. Nutrient application methods are mechanically intensive, requiring coverage of vast areas. Fertilizers may be solids, liquids, or gasses and, depending on the state of the product, may be applied using specialized trucks, tractors pulling sprayer equipment, or pressurized tanks to apply anhydrous ammonia. Techniques used to apply fertilizer include:

- *Band placement* is used to locate the fertilizer in an optimum position relative to the seed. This increases the potential for full utilization of the fertilizer by the crop and minimizes salt injury to the developing roots.

- *Broadcast application* refers to the practice of distributing the product uniformly over the soil surface. This method is preferred for lawns and forage and pasture crops and is the most common method used for crops. Tractors, airplanes, and helicopters are all used to broadcast fertilizers.

- *Manure injection* refers to the application of anhydrous ammonia. At normal pressure, anhydrous ammonia ($NH_3$) is a gas. For application as a fertilizer, it is pressurized to form a liquid. Because it is a volatile liquid, it is incorporated into the soil as a liquid under pressure to a depth of 15 to 25 cm. In the soil, $NH_3$ is converted to $NH_4^+$, which is stable. Gaseous ammonia is lost if soil pH increases much above 7, or as moisture fluctuates from field capacity. Liquid manure may be subsurface injected.

- *Addition of fertilizer to irrigation water (i.e., fertigation)* is a common practice in some areas and is usually part of a drip irrigation system that can apply water and fertilizer to a precise predetermined location.

- *Manure and biosolids* may be applied to the soil surface as a solid from a tractor-pulled box-type manure spreader as it makes passes across the field. Slurry manure and biosolids are generally applied to the soil surface by tractor-pulled or truck flail spreaders or to the subsurface by tractor or truck injection equipment. Liquid manure may be surface irrigated or subsurface injected. Manure and biosolid solids and slurries may be mechanically incorporated into the soil following application.

***Potential Pollution Outputs and Environmental Impacts***

There are several potential pollution outputs and environmental impacts from nutrient application and spills including runoff and leaching of nutrients which can contaminate surface water and groundwater; air emissions; and increases in the amount of soluble salts in soils. Runoff and leaching of nutrients typically occur when nutrients are applied excessively or improperly. Excessive amounts of soluble salts in the soil can prevent or delay seed germination, kill or seriously retard plant growth, and possibly render soils and groundwater unusable.

The degree of environmental impacts can depend on the application method. The surface application of fertilizer, manure, or biosolids is more likely to result in runoff than injection. Non-composted surface-applied manure will volatilize and release ammonia to the air. Spills of nutrients may also negatively impact the environment since they will be concentrated in one specific area.

***Pollution Prevention/Waste Minimization Opportunities***

There are several pollution prevention techniques that can be used to reduce pollution and impacts from nutrient application. These include:

- Application methods that prevent runoff (e.g., application by injection).
- Restricting application in close proximity to surface waters.
- Applying nutrients at agronomic (scientifically determined) rates to crops/cropland.
- Managing the site to eliminate erosion or reduce the runoff potential.
- Developing and implementing **nutrient management plans**. The primary purpose of nutrient management is to achieve the level of nutrients (e.g., nitrogen and phosphorus) required to grow the planned crop by balancing the nutrients that are already in the soil with those from other sources (e.g., manure, biosolids, commercial fertilizers) that will be applied. At a minimum, nutrient management can help prevent the application of nutrients at rates that will exceed the capacity of the soil and the planned crops to assimilate nutrients and prevent pollution.

  A site-specific nutrient management plan should be developed prior to planting, reviewed annually, and updated as needed. The plan, which will direct the application of one or more nutrients to the cropland, may include:

  - Soil and field maps that show setbacks and buffers, as well as wetland and groundwater maps
  - Crops and rotations
  - Soil tests
  - The calculated nutrient loading for each field

  Additional plan components may consist of manure and biosolid test results; projected manure production, storage, and treatment; commercial fertilizer needs; application rates; and the method and timing of application.

Soils, manure, and wastewater should be tested to determine nutrient content. Retesting should be completed following each significant change in the manure/biosolids source or manure waste management system.

- **Precision farming.** One of the more advanced technologies for improving nutrient application efficiency is known as precision farming. Typically used by larger operations, precision farming allows farmers to know their location in the field via a Global Positioning System (GPS) so that applications can be made according to a predetermined rate for that specific location. Precision farming may result in more precise applications of nutrients so there is little or no excess leached to groundwater or washed to surface waters.

### III.A.4. Applying Pesticides and Pest Control

Pesticides (e.g., insecticides, herbicides, fungicides) may be applied during all phases of crop production, including during harvesting and post-harvesting activities. For crop production, pesticides prevent insects and other pests, including weeds and other unwanted plants, from harming crops. Pesticide use has been encouraged by continuous cropping, which has created favorable pest habitats in certain crops.

Pesticide application methods for crops are mechanically intensive, requiring coverage of vast areas. Pesticides are applied directly to the plant or soil surface, incorporated into the soil, or injected as a gas through fumigation. One of the most common methods of applying pesticides to crops is liquid spraying. Liquid spraying may be conducted by aircraft, tractor spray rigs, or blasters.

- Aerial methods are the most common application type with about two-thirds of all insecticides and fungicides applied in this manner.

> Citrus groves may be aerially treated 10 to 20 times per season with insecticides, fungicides, and protectant oils.

  - Helicopters are often used because the turbulence from the main rotor tends to push the pesticides down toward the crop.

  - Fixed-wing aircraft are more commonly used in crops such as wheat and cotton.

- Tractor spray rigs are often used to apply herbicides in row crops because planting, fertilizing, and spraying can be accomplished in one pass through the field.

- Blasters are used for applying insecticides and fungicides to tree crops.

Other than the Agency's ultra-low volume exemption, concentrated pesticides must be applied according to label directions including any requirement to mix with a diluent or water. The mixing and subsequent loading into the application vehicle must be conducted in a contained area.

**Biopesticides**. Biopesticides (also known as biological pesticides) are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. At the end of 1998, there were approximately 175 registered biopesticide active ingredients and 700 products. Biopesticides fall into three major classes:

- *Microbial pesticides* contain a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient. These pesticides can kill many different kinds of pests. For example, there are fungi that control weeds, other fungi that control cockroaches, and bacteria that control plant diseases. The most widely used microbial pesticides include various types of the bacterium *Bacillus thuringiensis*, or Bt. Bt acts by producing a protein that kills the larvae of specific insect pests. One kind of Bt can control specific insects in cabbage, potatoes, and other crops, while another type of Bt kills mosquitoes. Based on available information, the bacterium appears to have no adverse effects on humans or the environment. However, additional data are needed to ensure that products containing this bacterium are safe for honey bees, wasps, fish, and aquatic invertebrates.

- *Plant pesticides* are pesticidal substances that plants produce from genetic material that has been added to the plants. For example, scientists can introduce the gene for the Bt pesticidal protein into a plant's genetic material. The plant will then manufacture the substance that destroys the pest. Both the Bt protein and its genetic material are regulated by EPA; the plant itself is not regulated.

- *Biochemical pesticides* are naturally occurring substances that control pests by nontoxic mechanisms. In contrast, conventional pesticides are synthetic materials that usually kill or inactivate the pest. Biochemical pesticides include substances, such as pheromones, that interfere with the growth or mating of a pest. Because it is sometimes difficult to determine whether a natural pesticide controls the pest by a nontoxic mode of action, EPA has established a committee to determine whether a pesticide meets the criteria of a biochemical pesticide.

Some of the advantages of using biopesticides are:

- They are inherently less harmful than conventional pesticides.

- They generally affect only the target pest and closely related organisms.

- They are often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.

To use biopesticides effectively, users should have a solid understanding of how to manage pests. When used as a component of integrated pest management (IPM) programs, biopesticides can greatly decrease the use of conventional pesticides, while still allowing crop yields to remain high.

***Potential Pollution Outputs and Environmental Impacts***

Environmental impacts most likely result from pesticide applications that are not conducted according to label directions. Potential pollution outputs and environmental impacts from pesticide application may include:

- Runoff or leaching of pesticides to surface water or groundwater. Pesticides incorporated into soil may leach into the groundwater. Soil fumigants will include releases to groundwater through leaching. Pesticides applied through chemigation, in which the pesticide is combined and applied with irrigation water, may be released to surface water through runoff or to groundwater through leaching.

- Air emissions. The application of pesticides using spray systems is more likely to involve releases to air. Soil fumigants will include releases to air through volatilization.

- Spills to soil and surface waters. The impacts of spills may be more significant since the spilled materials will be concentrated in one specific area.

- Potential human exposure and residue levels that exceed tolerance on animals and products. Pesticides are both suspected and known for causing immediate and delayed-onset health hazards for humans. If exposed to pesticides, humans may experience adverse effects, such as nausea, respiratory distress, or more severe symptoms up to and including death. To help reduce this potential exposure, tolerance levels have been established for residues on agricultural products. Animals and birds impacted by pesticides can experience similar illnesses or develop other types of physical distress. Following label directions for application, protective gear, and disposal will help ensure such environmental impacts do not occur.

- Pesticides that are applied to water-saturated soils or highly alkaline soils may not degrade as quickly as those applied properly or with the appropriate pH additive. When pesticides do not degrade, or do not bond with the plant or soil surface, they are more likely to be released to the environment through runoff.

- If not protected with backflow prevention devices, pesticides applied through spray systems that are connected to water supplies can siphon back to the water source and potentially contaminate drinking water systems. Also, improperly cleaned and disposed pesticide containers may cause releases to the soil and/or surface waters.

- Outputs from pesticide applications can inhibit crop production through the resurgence of pests after treatment, occurrence of secondary pest outbreaks, and development of pesticide resistance in target pests. In addition, the control of insects by broad-spectrum insecticides also destroys beneficial insect populations. Populations of many previously innocuous species may then increase rapidly and cause major economic damage.

- Crop losses have occurred when pesticides were applied improperly or drifted from a treated crop to nearby susceptible crops; when excess residues prevent crops from being planted in rotation or inhibit the growth of susceptible crops; and when excessive residues of pesticides accumulate on crops, causing the harvested products to be unmarketable.

***Pollution Prevention/Waste Minimization Opportunities***

Environmental impacts from pesticides are minimized by following label directions for application, and preventing or minimizing their use wherever possible. Pesticide use accounts for a substantial portion of farm production costs. By reducing their use, agricultural establishments cannot only reduce production costs, but also reduce environmental impacts of their operations.

Pesticide use and impact can also be minimized by using integrated pest management approaches, new technologies, efficient application methods, controls, and basic preventive measures. Examples of these are presented below.

- **Integrated pest management (IPM).** IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

  Crop management is a vital part of IPM because it may reduce the concentration of pests. Crop rotation can help prevent disease buildup. Rotation is particularly important when conservation tillage methods are used. For grain crops, other methods include planting of hybrid plants that are resistant to leaf blights and stalk rot, plowing under chopped corn stalks and leaves (which can kill some overwintering disease fungi, but also may promote the growth of others that live below the surface), and maintaining good drainage. An IPM plan should indicate that when a pesticide is needed, and its selection is based on persistence, toxicity, and leaching and runoff potential such that the most environmentally friendly pesticide is used.

- **Precision farming.** One of the more advanced technologies for improving nutrient and pesticide application efficiency is known as precision farming. Typically used by larger operations, precision farming allows farmers to know their location in the field via a Global Positioning System (GPS) so that applications can be made according to a predetermined rate for that specific location. Precision farming may result in more precise applications of nutrients and pesticides so there is little or no excess leached to groundwater or washed to surface waters.

- **Controlled droplet application (CDA).** CDA produces spray droplets that are relatively uniform in size and allows the applicator to control droplet size. In contrast, conventional spray nozzles produce droplets that vary widely from small droplets that may drift or evaporate before reaching the target, to large droplets that concentrate too much of the pesticide in one spot. CDA improves the efficiency of pesticide application, thus reducing overall pesticide use and cost. In addition, CDA may require less than one gallon of water per acre, compared with 20-30 gallons per acre with most conventional herbicide sprayers. CDA also provides time and fuel savings as well as less soil compaction. (Cornell University, Dr. Russel R. Hahn, *Controlled Droplet Application*)

- **Chemigation**. Another method of more efficient pesticide application is chemigation. Chemigation systems are irrigation systems that are designed for chemical application by injection with the irrigation water. The systems provide reduced water pollution by allowing prescription chemical applications to be made. If chemicals are applied frequently and only in amounts required by the irrigated crop, the presence of excessive amounts are avoided, thus preventing leaching from occurring. (University of Florida Cooperative Extension Service, 1993)

- **Erosion control devices.** To control pesticide losses to surface water, a farm should control erosion and reduce the volume of runoff water that leaves the field or farm. Practices such as conservation tillage, terraces, strip-cropping, and contouring reduce runoff and control erosion. Sediment basins, farm ponds, and wetlands contain or trap sediments. Keeping the chemicals in the field or trapping them in biologically active areas (e.g., ponds or wetlands) provides the opportunity for microorganisms to degrade the pesticides, eventually rendering them harmless.

- **Basic preventive measures**. Waste minimization strategies for pesticides include:

  - Buy only the amount needed for a year or a growing season.
  - Minimize the amount of product kept in storage.
  - Calculate how much diluted pesticide will be needed for a job and mix only that amount.
  - Apply pesticides with properly-calibrated equipment.
  - Use all pesticides in accordance with label instructions.
  - Purchase pesticide products packaged in such a way as to minimize disposal problems.
  - Work with the state to locate a pesticide handler who can use the excess pesticide.
  - Return unused product to the dealer, formulator, or manufacturer.
  - Implement setbacks from wellheads for application and storage.
  - Use contact pesticides that do not have to be incorporated into the soil.
  - Use row banding application techniques, where appropriate, to limit the amount of pesticide applied.
  - If possible, choose nonleachable pesticides labeled for the crop and pest. Nonleachable pesticides are considered those that are less likely to migrate from their target crop.

### III.A.5. Irrigating Crops

Irrigation transports water to crops primarily for growth, but also to ease the shock following transplant and to keep the crops cool in arid or excessive heat conditions.

Irrigation has always been a component of crop production and provides many benefits. Over the past 150 years, the practice of irrigation has increased dramatically, increasing the number of farmable acres, producing consistent and often higher yields, and making agriculture possible in areas previously unsuitable for intensive crop production.

In addition to these recognized benefits of irrigation, other factors have contributed to the increase in its use. Investment in equipment to transport water for agricultural use has been stimulated by federal policies. Such policies have included high commodity support prices, tax incentives that include investment credits, and accelerated depreciation for equipment, water depletion allowances, and low interest rates.

In the western United States, irrigation has been encouraged by federal law, which has provided subsidized irrigation water to western growers for nearly a century. As this and other subsidy programs have declined, the number of irrigated acres has decreased. However, in the eastern states that have not received direct water subsidies in the past, the number of irrigated acres is expected to increase.

There are many different irrigation systems, all of which are designed to move water from its source to where it can be used for crop production. Irrigation water is typically obtained from pumping groundwater or surface waters from onsite sources or from offsite sources such as rivers, pipelines, canals and aqueducts that are operated by irrigation districts and private water companies. Irrigation methods may consist of flood, stationary, and traveling systems.

- Flood systems allow the water to gravity sheet flow across the cropland.

- Stationary systems include subsurface drip or trickle systems and aboveground systems, which are permanently piped and may or may not have spray heads.

- Traveling systems may be center pivot, linear-move, hard-hose, or cable-tow. Irrigation systems such as the center pivot and linear-move usually have multiple spray heads (guns). Hard-hose and cable-tow systems usually have a single spray head.

***Potential Pollution Outputs and Environmental Impacts***

The potential pollution outputs from irrigation include runoff and leachate contaminated with pollutants (e.g., nutrients and pesticides) and salinization. Water depletion is one of the significant environmental impacts of irrigation. Irrigation can deplete surface water supplies, not only from the removal of water from these sources to use for irrigation, but also from the reduced volume of water returning to surface water due to evaporation losses. Irrigation can also deplete groundwater supplies. Water tables have fallen, particularly in drier western states, because of large volumes of groundwater being used for irrigation. Not only has this resulted in less water for agriculture and other uses, it has also resulted in an increase in the cost of water for all users. Land subsidence of up to 10 feet has resulted in some areas because of groundwater withdrawals occurring at rates that exceeded groundwater recharge.

Irrigation contributes to the movement of nutrients and pesticides into surface waters and groundwater, particularly in sandy soils. The impacts of pollutants (e.g., nutrients, pesticides, and sediments) from irrigation-induced runoff are similar to those discussed in Section III.A.1.

Mineralization and salinization of soils are additional impacts of irrigation. Irrigation water, whether from groundwater or surface water sources, has a natural base load of dissolved mineral salts. As the water is consumed by plants or lost to the atmosphere by evaporation, the salts remain and become concentrated in the soil. This is referred to as the "concentrating effect." The total salt load carried by irrigation return flow is the sum of the salt remaining in the applied water plus any salt picked up from the irrigated land. Irrigation return flows provide the means for conveying the salts to the surface water or groundwater supplies. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that use is impaired. However, if the process of water diversion for irrigation and the return of salinated water is repeated many times along a surface water, water quality will be progressively degraded for downstream irrigation use as well as for other uses. In the western states, major aquifers have been depleted or destroyed through salinization, or when withdrawals exceeded recharge rates.

***Pollution Prevention/Waste Minimization Opportunities***

There are several pollution prevention opportunities for irrigating crops. First, minimizing the use of irrigation will reduce erosion, runoff, groundwater depletion, and salinization. It can also save money by reducing the costs associated with irrigation. Other pollution prevention techniques include:

- *Using well-designed irrigation systems*. A common cause of environmental impacts from irrigation is poor system design. Poorly designed systems may apply water nonuniformly, allowing some areas to become oversaturated while others do not receive adequate water. Areas not adequately irrigated may suffer yield or quality reductions, while overirrigated areas may suffer from the leaching of chemicals.

- *Using efficient irrigation systems*. There are several types of efficient irrigation systems, including surge irrigation systems and drip irrigation systems.

    - With surge irrigation, water is sent through the furrows between each row of crops. Rather than sending all the water at once, small amounts are sent in bursts. In this manner, erosion is reduced, more water reaches the plant, and less runoff of irrigated water occurs.

    - In drip irrigation, plants are watered directly from the irrigation source. While drip irrigation conserves water, by watering only the plants' fruits and the soil immediately around them, drip irrigation can also lead to soil erosion. If drip irrigation is the sole method used, the soil between rows of crops remains dry, thus making it more susceptible to wind erosion.

The Texas Agricultural Extension Service has found irrigation efficiency for surge irrigation up to 90 percent and drip irrigation to be up to 98 percent. These systems significantly reduce the amount of irrigation water that can runoff to surface waters, thus reducing pollution. Conventional systems have a much lower efficiency rate. The efficiency of all methods can be improved by varying application volumes as water tables rise and fall.

**Calculating Fuel Use Efficiency for Irrigation Pumps**

The Texas Agricultural Extension Service has developed a program to determine the efficiency of various irrigation methods. The program calculates a pumping plant's fuel use efficiency performance and compares it to a given standard. The program also calculates the fuel cost per acre-inch pumped and fuel cost savings if a pumping system is brought up to the performance standard. The program can be used to evaluate the pumping performance and fuel cost for the following fuels: (1) electricity, (2) natural gas, (3) diesel, (4) gasoline, (5) propane, and (6) butane.

In addition to well-designed and efficient irrigation systems, there are many inexpensive best management practices that can be used to reduce runoff and erosion, and lower irrigation costs. These methods include the following:

- Assure all irrigation systems are in good repair, with no leaks, and that the sprinklers are adjusted to minimize misdirected spray.
- Use low-volume spray heads and stop watering if puddling and runoff is observed.
- Irrigate early in the morning or in the evening when it is generally less windy and cooler.
- Utilize efficient irrigation methods such as drip irrigation. Many existing spray systems can be changed to function as drip systems.
- Install check valves to prevent downhill sprinkler heads from draining after the system has been shut off. This keeps water in the pipes for the next sprinkling. Follow manufacturer's instructions.
- Install "rainguards" that measure rainfall and stop operation of the irrigation controller during rainfall.
- If nutrients are irrigated, calculate the discharge rate of the system and irrigate only at desired loading.
- Replace worn irrigation nozzles (increased orifice size) that may result in over application.

### III.A.6. Harvesting Crops and Post-Harvesting Activities

Harvesting crops involves digging, cutting, picking, or other methods of removing the crops from the ground, stalks, vines, or trees. Small fruits and other food crops (e.g., strawberries, melons) are typically harvested by hand, though may be harvested by machine. Field crops (e.g., corn, barley, oats) are typically harvested by machine. For specific crops, such as sugar cane, pre-harvest burning may be conducted to improve access to the crop.

Post-harvesting activities include washing and processes products; packaging, loading, and transporting products; and destroying crop residue (if appropriate).

- *Washing, processing, and packaging products*. Crops may be washed at the agricultural establishment or at the processing plant. Fresh agricultural crops may be washed at the agricultural establishment and then shipped directly to distribution centers or sales outlets. Agricultural crops destined for use as processed foods (e.g., canned fruits and vegetables or snack foods), are likely to undergo extensive washing and processing at the processing plant. Unusable crops can either be picked up manually or separated out from the usable stock after the washing process.

  Following processing, crops are packaged and prepared for delivery to the appropriate customer. Crops such as tobacco require drying during the onsite curing processing. Crops may be packaged using various materials, including corrugated cardboard, paper, and plastic/fabric packaging materials.

- *Loading and transporting products*. While the loading operation will vary between establishments, individually packaged crops (e.g., berries), are commonly loaded by forklift or by hand, while bulk packaged crops (e.g., potatoes and apples) may be loaded by conveyor. Crops are then transported typically by truck or rail to their final destination.

- *Destroying crop residue*. Post-harvest crop residue destruction is a practice used for specific crops, particularly in certain areas of the United States. For example, rice and wheat stubble are often burned in the southeast and northwest respectively after harvest is complete.

***Potential Pollution Outputs and Environmental Impacts***
The potential pollution outputs of harvesting and post-harvesting activities include air emissions from harvesting equipment and crop residue burning; unusable or spilled crop; wastewater potentially contaminated with organic wastes and pesticides from crop washing; wastewater and waste product from processing; and damaged or unusable packaging materials. If discharged to surface waters, wastewater from crop washing can potentially cause BOD contamination. Damaged or unusable packaging and unusable/spilled crop may be managed as solid waste. Hydraulic lifts or conveyors used in the loading process may leak oil, resulting in soil contamination.

***Pollution Prevention/Waste Minimization Opportunities***
There are several pollution prevention and waste minimization opportunities for harvesting and post-harvesting activities. These include:

- *Maintaining harvesting machinery and vehicles*. Section III.A.7. *Maintaining and Repairing Agricultural Machinery and Vehicles* discusses various methods of keeping an environmentally responsible farm vehicle.

- *Using unusable product as nutrients*. Unusable products can be washed to remove pesticides and then composted for future use as nutrients. This can prevent the disposal of these products as solid wastes and reduce the amount of commercial fertilizers used.

- *Minimizing water use for product washing*. Minimizing the amount of water used for product washing can reduce potential BOD contamination and reduce water costs. There are several types of equipment that can be used to minimize water use including control faucets and sprayers. These faucets and sprayers control the flow of water, using significantly less water than the faucets that supply a continuous flow of water. Other simple techniques to minimize water use include the following:

  - Installing a time sequence sprayer that can minimize the amount of water being used.

  - Using a high-pressure, low-flow nozzle during cleaning to significantly reduce water use.

  - Installing sideboards or splash guards to prevent spillage.

  - Shutting the water off during breaks.

- *Prevent contamination from oil leaks*. Place catch pans underneath hydraulic lifts or conveyors to collect oil leaks and prevent soil contamination. This oil can then be recycled.

- *Prevent product spills.* The use of sideboards on conveyors or other equipment designed to transport products from the ground into the vehicle can be used to prevent product spills. Additionally, catch pans or containers underneath loading areas can be used to collect any unusable products left on the ground. These products can then be composted, if appropriate.

### III.A.7. Maintaining and Repairing Agricultural Machinery and Vehicles

Day-to-day maintenance and repair activities keep agricultural machinery and vehicles safe and reliable. Maintenance activities include oil and filter changes, battery replacement, and repairs, including metal machining.

***Potential Pollution Outputs and Environmental Impacts***

The wastes from maintenance and repair activities can include used oil, spent fluids, spent batteries, metal machining wastes, spent organic solvents, and tires. These wastes have the potential to be released to the environment if not handled properly, stored in secure areas with secondary containment, protected from exposure to weather, and properly disposed of. If released to the environment, the impact of these releases can be contamination of surface waters, groundwater, and soils, as well as toxic releases to the atmosphere. Groundwater pollution can also result from discharges of wastes to Class V wells.

**Proper Disposal of Oil-Based Fluids**. Spent petroleum-based fluids and solids should be sent to a recycling center whenever possible. Solvents that are hazardous waste must not be mixed with used oil or, under RCRA regulations, the entire mixture may be considered hazardous waste. Non-listed hazardous wastes can be mixed with waste oil, and as long as the resulting mixture is not hazardous, can be handled as waste oil. All used drip pans and containers should be properly labeled.

***Pollution Prevention/Waste Minimization Opportunities***

Preventive maintenance programs can minimize waste generation, increase equipment life, and minimize the probability of significant impacts and accidents. Where the wastes cannot be eliminated, safe handling and recycling can minimize environmental impacts. The following presents pollution prevention/waste minimization opportunities for each type of waste.

**Used Oil**. The impact of oil changes can be minimized by preventing releases of used oil to the environment, and recycling or reusing used oil whenever possible. Spills can be prevented by using containment around used oil containers, keeping floor drains closed when oil is being drained, and by training employees on spill prevention techniques. Oil that is contained rather than released can be recycled, thus saving the farm money, and protecting the environment.

Recycling used oil requires equipment like a drip table with a used oil collection bucket to collect oil dripping from parts. Drip pans can be placed under machinery and vehicles awaiting repairs to capture any leaking fluids. By using catch pans or buckets, rather than absorbent materials to contain leaks or spills of used oil, the used oil can be more easily recycled. To encourage recycling, the publication “How To Set Up A Local Program To Recycle Used Oil” is available at no cost from the RCRA/Superfund Hotline at 1-800-424-9346 or 1-703-412-9810.

**Spent Fluids**. Farm machinery and vehicles require regular changing of fluids, including oil, coolant, and others. To minimize releases to the environment, these fluids should be drained and replaced in areas where there are no connections to storm drains or municipal sewers. Minor spills should be cleaned up prior to reaching drains. Used fluid should be collected and stored in separate containers. Fluids can often be recycled. For example, brake fluid, transmission fluid, and gear oil are recyclable. Some liquids are able to be legally mixed with used motor oil which, in turn, can be reclaimed.

During the process of engine maintenance, spills of fluids are likely to occur. The “dry shop” principle encourages spills to be cleaned immediately so that spilled fluid will not evaporate to air, be transported to soil, or be discharged to waterways or sewers. The following techniques help prevent and minimize the impact of spills:

- Collect leaking or dripping fluids in designated drip pans or containers. Keep all fluids separated so they may be properly recycled.

- Keep a designated drip pan under the vehicle while unclipping hoses, unscrewing filters, or removing other parts. The drip pan prevents splattering of fluids and keeps chemicals from penetrating the shop floor or outside area where the maintenance is occurring.

- Immediately transfer used fluids to proper containers. Never leave drip pans or other open containers unattended.

Radiator fluids are often acceptable to antifreeze recyclers. This includes fluids used to flush out radiators during cleaning. Reusing the flushing fluid minimizes waste discharges. If a licensed recycler does not accept the spent flushing fluids, consider changing to another brand of fluid that can be recycled.

**Batteries**. Farm operators have three options for managing used batteries: recycling through a supplier, recycling directly though a battery reclamation facility, or direct disposal. Most suppliers now accept spent batteries at the time of new battery purchase. While some waste batteries must be handled as hazardous waste, lead acid batteries are not considered hazardous waste as long as they are recycled. In general, recycling batteries may reduce the amount of hazardous waste stored at a farm, and thus reduce the farm's responsibilities under RCRA.

The following best management practices are recommended to prevent used batteries from impacting the environment prior to disposal:

- Place on pallets and label by battery type (e.g., lead-acid, nickel, and cadmium).

- Protect them from the weather with a tarp, roof, or other means.

- Store them on an open rack or in a watertight secondary containment unit to prevent leaks.

- Inspect them for cracks and leaks as they come to the farm. If a battery is dropped, treat it as if it is cracked. Acid residue from cracked or leaking batteries is likely to be hazardous waste under RCRA because it is likely to demonstrate the characteristic of corrosivity, and may contain lead and other metals.

- Neutralize acid spills and dispose of the resulting waste as hazardous if it still exhibits a characteristic of a hazardous waste.

- Avoid skin contact with leaking or damaged batteries.

**Machine Shop Wastes**. The major hazardous wastes from metal machining are waste cutting oils, spent machine coolant, and degreasing solvents. Scrap metal can also be a component of hazardous waste produced at a machine shop. Material substitution and recycling are the two best means to reduce the volume of these wastes.

The preferred method of reducing the amount of waste cutting oils and degreasing solvents is to substitute with water-soluble cutting oils. If non-water-soluble oils must be used, recycling waste cutting oil reduces the potential environmental impact. Machine coolant can be recycled, either by an outside recycler, or through a number of in-house systems. Coolant recycling is most easily implemented when a standardized type of coolant is used throughout the shop. Reuse and recycling of solvents also is easily achieved, although it is generally done by a permitted recycler. Most shops collect scrap metals from machining operations and sell these to metal recyclers. Metal chips which have been removed from the coolant by filtration can be included in the scrap metal collection. Wastes should be carefully segregated to facilitate reuse and recycling.

### III.A.8. Fuel Use and Fueling Activities

Fuel is used to operate agricultural machinery, equipment, and vehicles that are used throughout almost every step of crop production, including preparing the site/soil, planting and tending the crops, applying nutrients and pesticides, irrigating and harvesting the crops, and post-harvesting activities. Agricultural machinery and vehicles are typically fueled using an aboveground fueling dispenser that is connected to an aboveground or underground fuel tank.

***Potential Pollution Outputs and Environmental Impacts***
Agricultural machinery and vehicles that use fuel most likely emit pollutants to the atmosphere. The activity of fueling itself can emit air

pollutants, and spills of fuel can cause water, soil and groundwater contamination. Underground fueling systems that are not monitored or maintained properly can leak into the surrounding soils and eventually contaminate groundwater.

***Pollution Prevention/Waste Minimization Opportunities***
Properly maintaining fuel tanks, lines, and fueling systems can substantially reduce the probability of accidental fuel spills or leaks. All leaking pipe joints, nozzle connections, and any damage to the fueling hose (e.g., kinks, crushing, breaks in the carcass, bulges, blistering, soft spots at the coupling, deep cracks or cuts, spots wet with fuel, or excessive wear) should be fixed immediately to reduce the amount of pollution to the environment. Spill and overflow protection devices can be installed to prevent fuel spills and secondary containment can be used to contain spills or leaks. Additional pollution prevention techniques for fueling include the following:

- Inspect fueling equipment daily to ensure that all components are in satisfactory condition. While refueling, check for leaks.
- If refueling occurs at night, make sure it is carried out in a well-lighted area.
- Never refuel during maintenance as it might provide a source of ignition to fuel vapors.
- Do not leave a fuel nozzle unattended during fueling or wedge or tie the nozzle trigger in the open position.
- Discourage topping off of fuel tanks.

## III.A.9. Maintaining the Facility

**Providing Drinking Water**
As part of maintaining the physical site, an owner often is responsible for providing and maintaining a safe source of drinking water for those individuals who live or work at the site. Water provided from a surface water supply or groundwater supply may be considered a public water system and, as such, is subject to federal regulations. To be

> A public water system is a system that receives water from a well, river, reservoir, or other sources, and serves piped water to at least 15 service connections or regularly serves an average of 25 people each day for at least 60 days.

subject to the Safe Drinking Water Act, the system must meet set criteria such that it is classified as one of the following water systems: community, non-transient non-community, or transient non-community. To ensure the drinking water source, whether surface or groundwater, is not contaminated, the regulations require the owner of the public water system to conduct periodic monitoring and analyses.

***Potential Pollution Outputs and Environmental Impacts***
Surface water supplies may become contaminated through runoff. Groundwater supplies may become contaminated through a variety of sources, including runoff and leaching, improperly grouted wellheads, improperly constructed or sited wellheads, or faulty onsite septic systems. Potential environmental impacts from contaminated drinking water include a wide variety of health effects for those who ingest it. Depending on the contaminant, the water may cause short-term illnesses and may also lead to long-term health effects.

***Pollution Prevention/Waste Minimization Opportunities***
The primary concern with drinking water is to ensure it does not become contaminated. The previous sections of this chapter discussed the pollution prevention methods associated with crop production that can help ensure that surface water or groundwater does not become contaminated, and thus result in contaminated drinking water.

**Managing Equipment Containing PCBs**
Facility maintenance includes managing equipment that may contain PCBs, such as generators, electrical transformers and their bushings, capacitors, reclosers, regulators, electric light ballasts, and oil switches. Facilities must ensure through activities related to the management of PCBs (e.g., inspections, proper storage) that human food or animal feed are not exposed to PCBs.

***Potential Pollution Outputs and Environmental Impacts***
The potential pollution outputs are spills or leaks of PCB-containing oil from this equipment and hazardous air emissions in the event of an electrical fire. These releases can result in air, water, and soil contamination. While the regulations do not establish a specific distance limit, any item containing PCBs is considered to pose an unacceptable exposure risk to food or feed if PCBs released in any form have the potential to reach/contaminate food or feed.

***Pollution Prevention/Waste Minimization Opportunities***
There are several techniques that can be used to prevent releases of PCBs to the environment and contamination of food or feed. These

include replacing the PCB-containing equipment; replacing the PCB-containing oil with oil that does not contain PCBs; providing secondary containment of the equipment so that spills cannot contaminate the soil or groundwater; and relocating the equipment to a location that does not present an exposure risk to food or feed. PCB-containing equipment should be inspected regularly for leaks and any deterioration that may cause an electrical fire.

**Renovating and Demolishing Structures**

Asbestos and lead-based paint may be present in structures that are being renovated or demolished. While EPA banned the use of many asbestos-containing materials in the 1970s, buildings built before this are likely to have asbestos-containing materials. Used as insulation and a fire retardant, asbestos and asbestos-containing materials can be found in a variety of building construction materials, including pipe and furnace insulation materials, asbestos shingles, millboard, textured paint and other coating materials, and floor tiles. It is also found in vehicle brake linings. Lead-based paint can typically be found on the interiors and exteriors of buildings constructed prior to 1978. This is because EPA banned the manufacture and use of lead-based paint and lead-based paint products in 1978.

***Potential Pollution Outputs and Environmental Impacts***

The renovation and demolition of structures can impact the environment as materials that may have previously been trapped within or on buildings become exposed to the environment. When encapsulated, asbestos fibers do not impact human health or the environment. However, during renovation or demolition, asbestos fibers may be released. If inhaled or ingested, asbestos fibers can cause respiratory damage.

Lead is a known carcinogen through any exposure pathway and may result in significant health effects. As with asbestos, lead-based paint that remains intact and is not chipping or otherwise deteriorating, does not present health problems. However, when it does become damaged, it should be properly removed, contained, and disposed of to prevent exposure. The activity of paint removal has the potential to impact human health and the environment as lead-containing fibers, dust, and paint chips are released. Paint chips and dust can cause indoor air contamination during renovation, and soil contamination from demolition or improper disposal. In addition, lead-based paint chips and dust, if ingested, can create severe, long-term health effects, especially for children.

***Pollution Prevention/Waste Minimization Opportunities***
The potential impact can be mitigated by assuring any asbestos is encapsulated within the building structure while the building is being used, and properly contained during construction and demolition.

## III.B. Greenhouses and Nurseries: Operations, Impacts, and Pollution Prevention Opportunities

This section provides an overview of commonly employed operations and maintenance activities at greenhouses and nurseries. This discussion is not exhaustive; the operations and maintenance activities discussed are intended to represent the major sources pollution outputs and environmental impacts from producing greenhouse and nursery products. General pollution prevention and waste minimization opportunities are also discussed in the context of each operation.

Facilities that are engaged in greenhouse and nursery operations (e.g., horticulture), are responsible for growing and selling greenhouse and nursery products. Many of the activities related to horticulture production are quite similar to those necessary for production of crops. As a result, the material inputs, pollution outputs, and potential environmental impacts are very similar to those discussed throughout Section III.A.

While this section focuses on those activities for operations that fall under NAICS code 0114 (SIC code 018), many of these activities also take place under other parts of NAICS code 011 - Crop Production (SIC code 01). In contrast to food crops, horticultural production may include maintenance of plants and trees for two or more growing seasons. While food crops are harvested to be consumed, horticulture products are often sold live. Furthermore, horticulture production includes activities that take place both indoors and in the open air.

This section describes the following horticultural production activities:

- Preparing soil/growing media for horticulture crops
- Planting horticulture crops
- Applying nutrients to horticulture crops
- Applying pesticides and pest control for horticulture crops
- Irrigating horticulture crops
- Tending and harvesting horticulture crops
- Constructing and maintaining greenhouses
- Transporting products
- Maintaining and repairing equipment

- Fuel use and fueling equipment

Exhibit 21 presents material inputs and pollution outputs from each of these processes.

**Exhibit 21. Greenhouse and Nursery Production Activities, Raw Material Inputs, and Pollution Outputs**

| Activity | Raw Material Input | Pollution Output |
|---|---|---|
| Preparing soil/growing media | S Soil, peat, or other synthetic growing media<br>S Lime | S Air emissions (e.g., dust)<br>S Sediment, nutrient, and pesticides runoff from soil erosion |
| Planting | S Seeds, seedlings | S Air emissions (e.g., dust)<br>S Sediment, nutrient, and pesticide runoff from soil erosion<br>S Plants, branches, leaves, etc. |
| Applying nutrients | S Organic nutrients<br>S Commercial nutrients<br>S Water | S Runoff and leaching of unused or misapplied nutrients<br>S Chemical air emissions |
| Applying pesticides and pest control | S Pesticides (including insecticides, rodenticides, fungicides, and herbicides) | S Runoff and leaching of unused or misapplied nutrients<br>S Chemical air emissions |
| Irrigating (not including nutrient application) | S Water<br>S Chemicals | S Runoff contaminated with sediments, salts, pesticides, and nutrients |
| Tending and harvesting | | S Plant and tree clippings |
| Constructing and maintaining greenhouses | S Construction materials<br>S Fuel for heating and cooling<br>S Boiler chemicals | S Construction wastes<br>S Air emissions<br>S Storm water runoff from increased impervious area<br>S Spills of boiler chemicals |
| Packaging, loading, and transporting horticulture crops | S Plastic, burlap or paper packaging materials | S Dead plants<br>S Waste packaging materials |

**Exhibit 21. Greenhouse and Nursery Production Activities, Raw Material Inputs, and Pollution Outputs**

| Activity | Raw Material Input | Pollution Output |
|---|---|---|
| Maintaining and repairing equipment | • Oil<br>• Lubricating fluids<br>• Fuel<br>• Coolants<br>• Solvents<br>• Tires<br>• Batteries<br>• Equipment parts | • Used oil<br>• Spent fluids<br>• Spent batteries<br>• Metal machining wastes<br>• Spent organic solvents<br>• Tires<br>• Air, water, soil, and groundwater pollution resulting from spilled and/or spent fluids |
| Fuel use and fueling activities | • Fuel | • Air emissions from machinery<br>• Air, water, soil, and groundwater pollution resulting from spills |

### III.B.1. Preparing Soil/Growing Media for Horticulture Crops

Prior to planting, the soil or growing media[3] must be prepared for growing horticulture crops. For horticulture crops grown outdoors, soil preparation generally involves tilling and the application of nutrients, primarily commercial fertilizer. Tilling aerates the soil, allows seedlings to be placed in the soil, and helps roots take hold of the soil. It also improves drainage and allows for better assimilation of nutrients (i.e., fertilizers) and pesticides into the soil. For greenhouse crops, proper soil or media preparation is key for fostering plant growth. Due to the relatively shallow depth and limited volume of greenhouse containers, soil must be amended to provide the physical and chemical properties necessary for plant growth.[4] Materials are added to the soil that promote improved aeration, drainage, and water holding capacity. These materials can include peat and peat-like materials, wood residues, rice hulls, sand, vermiculite, calcined clays, expanded polystyrene, urea formaldehydes, and bagasse (a waste byproduct of the sugar industry that is often composted to promote aeration). In addition, soil pH is often

[3] Note that many indoor growing operations use non-soil media consisting of peat moss, compost, lime, and other material, rather than soil in order to provide a more porous growth environment in a relatively small volume container.

[4] *Texas Greenhouse Management Handbook*, Dr. Don Wilkerson, Texas Agricultural Extension Service, http://aggie-horticulture.tamu.edu/greenhouse/guides/green/green.html.

adjusted by adding ground limestone, hydrated lime, or dolomitic lime to suit the plants being grown.[5]

***Potential Pollution Outputs and Environmental Impacts***

The major environmental impacts of soil/growing media preparation in horticulture operations is runoff that carries pollutants (e.g., soils/growing media, nutrients, pH adjusting agents, pesticides) to groundwater or surface waters.

For outdoor operations, the primary pollution output is runoff contaminated with pollutants (e.g., sediments, nutrients, and pesticides) caused by soil erosion. Soil erosion causes damage both onsite and offsite at horticulture operations. Onsite erosion can reduce the productivity of the operation and increase the need for fertilizer and other inputs. Pollutants (e.g., sediments, nutrients, and pesticides) that are transported offsite by runoff may be deposited in surface waters, leading to reduced oxygen content, increased algae growth, and overall degradation of water quality.

Indoor operations can also be sources of water pollution. Runoff that comes in contact with spills of soil/soil media, improperly managed outdoor bulk soil/media piles, or discharges of floor washdown water can transport sediments and other pollutants to surface waters. Spilled or excessively applied lime also has the potential to contaminate groundwater or surface waters.

***Pollution Prevention/Waste Minimization Opportunities***

When preparing soil for outdoor operations, runoff can be reduced by planting and maintaining buffer strips of grass and sod. These strips can slow runoff and trap sediment, reducing soil loss and potentially preventing water contamination. Horticulture operations that maintain grass strips between rows of plants or trees have been shown to maintain 30 percent to 50 percent more soil than those that maintain only bare soil.[6]

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[5] *Effect of pH on Pesticide Stability and Efficacy*, Winand K. Hock, Penn State University, http://pmep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-ph.html.

[6] *Best Management Practices for Field Production of Nursery Stock*, North Carolina State University Biological and Agricultural Engineering Extension Service, http://www.bae.ncsu.edu/programs/extension/ag-env/nursery/.

Unnecessary application of materials that could potentially leach into and pollute nearby water sources can be prevented through frequent soil testing prior to application. Spills can be prevented by assuring the integrity of the containers in which the materials are kept. Containers should be routinely repaired and replaced if perforated.

### III.B.2. Planting Horticulture Crops

Horticulture crops are planted after the soil/soil media is prepared. Planting involves the placement of seeds or seedlings into the soil/soil media. Planting is typically done by hand for greenhouse operations, while planting may be done either by hand or mechanically for nursery operations.

***Potential Pollution Outputs and Environmental Impacts***
The major inputs in planting horticulture crops are the seeds and energy used to plant them. The pollutant outputs include air emissions from any planting equipment.

***Pollution Prevention/Waste Minimization Opportunities***
Pollution prevention opportunities during the planting process for horticulture operations are similar to those discussed in Section III.A.2.

### III.B.3. Applying Nutrients to Horticulture Crops

During all phases of the crop production process, nutrients (e.g., fertilizer, manure, biosolids) can be applied to horticulture crops. Nutrients enhance crop growth by providing essential nitrogen, phosphorus, potassium, and micro-nutrients. Nutrients can be applied directly to the plant or soil surface, incorporated into the soil, or applied with irrigation water through chemigation.

Most greenhouse operations use liquid fertilizers, supplemented by granular or slow release fertilizers which are added to the growing medium. While the frequency of fertilizer application may vary, many operations continuously fertilize through irrigation systems. For outdoor operations, nutrient application is often more mechanically intensive, requiring coverage of large areas. Nearly all acres planted are treated with one or more types of nutrients (e.g., fertilizers, manure, or biosolids). Depending on the timing of the seed planting, the application may occur simultaneously.

For outdoor operations, fertilizers may be applied in solid, liquid, or gas form. Depending on the state of the product, nutrients may be applied using specialized trucks to apply dry product, tractors to pull sprayer equipment for liquids, and pressurized tanks to apply anhydrous ammonia. Techniques used to apply fertilizer include the following:

- *Band placement* is used to locate the fertilizer in an optimum position relative to the seed. This minimizes salt injury to the developing roots.

- *Broadcast application* refers to the practice of distributing the product uniformly over the soil surface. Tractors, airplanes and helicopters are used to broadcast fertilizers.

- *Injection* refers to the application of anhydrous ammonia. At normal pressure, anhydrous ammonia ($NH_3$) is a gas. For application as a fertilizer, it is pressurized to form a liquid. Because it is a volatile liquid, it is incorporated into the soil as a liquid under pressure to a depth of 15 to 25 cm. In the soil, $NH_3$ is converted to $NH_4^+$, which is stable. Gaseous ammonia is lost if soil pH increases much above 7, or as moisture fluctuates from field capacity.

- *Addition of fertilizer to irrigation water* (known as fertigation), is usually part of a drip irrigation system that can apply water and fertilizer to a precise predetermined location.

- *Manure and biosolids* may be applied to the soil surface as a solid from a tractor-pulled box-type manure spreader as it makes passes across the field. Slurry manure and biosolids are generally applied to the soil surface by tractor-pulled or truck flail spreaders or subsurface by tractor or truck injection equipment. Liquid manure may be surface irrigated or subsurface injected. Manure and biosolid solids and slurries may be mechanically incorporated into the soil following application.

***Potential Pollution Outputs and Environmental Impacts***

There are several potential pollution outputs and environmental impacts from nutrient application and spills including runoff and leaching of improperly or excessively applied nutrients which can contaminate surface water and groundwater; air emissions; and increases in the amount of soluble salts in soils. Excessive amounts of soluble salts in the soil can prevent or delay seed germination, kill or seriously retard plant growth, and possibly render soils and groundwater unusable.

The degree of environmental impacts depends on the application method. The surface application of fertilizer, manure, or biosolids is more likely to result in runoff than injection. Non-composted surface-applied manure will volatilize and release ammonia to the air. Spills of nutrients may also negatively impact the environment since they will be concentrated in one specific area.

***Pollution Prevention/Waste Minimization Opportunities***
There are several pollution prevention techniques that can be used to reduce pollution and impacts from nutrient application. These include:

- Application methods that prevent runoff (e.g., application by injection).
- Restricting application in close proximity to surface waters.
- Applying nutrients at agronomic rates to crops/cropland.
- Managing the site to eliminate erosion or reduce the runoff potential.
- Developing and implementing **nutrient management plans**. The primary purpose of nutrient management is to achieve the level of nutrients (e.g., nitrogen and phosphorus) required to grow the planned crop by balancing the nutrients that are already in the soil with those from other sources (e.g., manure, biosolids, commercial fertilizers) that will be applied. At a minimum, nutrient management can help prevent the application of nutrients at rates that will exceed the capacity of the soil and the planned crops to assimilate nutrients and prevent pollution. More information on nutrient management plans is presented in Section III.A.3.

### III.B.4. Applying Pesticides and Pest Control for Horticulture Crops

The pesticides commonly used in horticulture operations include insecticides, fungicides, and herbicides. For large nursery operations, pesticides are often applied through liquid spraying. As described in Section III.A.4., liquid spraying may be conducted by aircraft, tractor spray rigs, or blasters.

- Aerial methods are the most common spray applications, with about two-thirds of all insecticides and fungicides applied in this manner. Trees and shrubs may be aerially treated several times per season with insecticides, fungicides, and protectant oils. Helicopters are often used because the turbulence from the main rotor tends to push the pesticides down toward the plant.

- Tractor spray rigs provide an advantage where horticulture crops are grown in rows because planting, fertilizing and spraying can be accomplished in one pass through the field.

- Blasters can be used for applying insecticides and fungicides to trees.

***Potential Pollution Outputs and Environmental Impacts***
The potential environmental impacts from pesticide application are runoff or leaching to surface water or groundwater, spills to surface waters, potential human exposure, and soil contamination that could leave land unproductive. These environmental impacts may all occur if pesticides are not applied according to the label directions. Impacts from pesticide application to horticulture crops are similar to those discussed in Section III.A.4.

***Pollution Prevention/Waste Minimization Opportunities***
As discussed previously in Section III.A.4, the best way to prevent environmental impacts from pesticide use is follow label directions for application and prevent or minimize their use wherever possible. Pesticide use accounts for a significant portion of horticulture production costs. By reducing their use, horticulture operations cannot only reduce production costs, but also reduce environmental impacts from their operations. Pesticide use can be minimized by using integrated pest management approaches, new technologies, efficient application methods, controls, and basic preventive measures. Pollution prevention opportunities for reducing or minimizing impacts from application of pesticides are discussed in Section III.A.4.

### III.B.5. Irrigating Horticulture Crops

Irrigation transports water to horticulture crops to nourish the crops, ease the shock to the plants following transplant, and keep the crops cool in arid or excessive heat conditions. There are many different irrigation systems, all of which are designed to move water from its source to where it can be used for crop production. Irrigation water is obtained from onsite groundwater and surface water sources, as well as offsite sources such as rivers, pipelines, canals and aqueducts that are operated by irrigation districts and private water companies.

All greenhouse crops are irrigated on a regular basis (since they are enclosed and do not receive water from rainfall events). Water is generally applied to the upper surface of the soil/growing media by using overhead sprinklers, drip or trickle irrigation systems, hand-held hoses, or a combination of methods. The advantage of drip or trickle systems is that they minimize water use, leaching of nutrients in the growth media, and reduce the probability of root rot in excessively moist soil. Overhead sprinklers and hand water irrigation methods are often less expensive to implement, but use more water per plant.[7]

***Potential Pollution Outputs and Environmental Impacts***

For indoor operations, the primary pollution outputs are wastewater and runoff that contains nutrients and pesticides. For outdoor horticulture operations, the pollution outputs from irrigation include runoff and leaching of nutrients and pesticides, salinization, and groundwater depletion. The impacts of pollutants (e.g., nutrients, pesticides, and sediments) from irrigation-induced runoff are similar to those discussed in Section III.A.5.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention opportunity for irrigation is the use of irrigation methods which efficiently apply water, thereby reducing water use and the potential for runoff. One efficient application method is drip irrigation. Drip irrigation gradually applies water directly to the soil surface over extended periods of time (i.e., 1, 2, or 5 gallons per hour), resulting in less water loss due to evaporation or runoff. If nutrients are applied using drip irrigation, the amount of fertilizer used can also be reduced if the nutrients are applied at the utilization rate of the plant. In addition to the environmental benefits, drip irrigation tends to cause roots to concentrate within the limited wetted soil area, thus creating a more concentrated root ball. More concentrated root balls make the plants easier to ship and increase their ability to survive through the sale and planting process.[8] Section III.A.5 describes other potential pollution prevention opportunities associated with irrigation.

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[7] *Texas Greenhouse Management Handbook*, Dr. Don Wilkerson, Texas Agricultural Extension Service, http://aggie-horticulture.tamu.edu/greenhouse/guides/green/green.html.

[8] *Best Management Practices for Field Production of Nursery Stock*, North Carolina State University Biological and Agricultural Engineering Extension Service, http://www.bae.ncsu.edu/programs/extension/ag-env/nursery/.

### III.B.6. Tending and Harvesting Horticulture Crops

Horticulture crops must be maintained from planting through the point of sale. Each plant may be tended for one or several growing seasons. Tending horticulture crops involves applying water, nutrients, and pesticides; transplanting crops from small to larger pots or from pots to outside areas; and pruning trees and shrubs to enhance plant health and make them more aesthetically pleasing.

Harvesting of horticulture crops involves digging, cutting, or other methods of safely removing product from the ground, stalks, vines, or trees. Harvesting must be done with care to protect the plant and assure that it remains alive through the point of sale. For flowers, small plants, and greenhouse-grown vegetables, harvesting is generally done manually. For larger trees and shrubs, harvesting may be done by hand or by machine.

***Potential Pollution Outputs and Environmental Impacts***

The primary pollution outputs from tending and harvesting horticulture crops are plant clippings (e.g., branches, leaves, and flowers) that have been removed during the tending/pruning activities.

***Pollution Prevention/Waste Minimization Opportunities***

There are several pollution prevention and waste minimization opportunities for tending and harvesting activities. These include:

- *Maintaining harvesting machinery and vehicles*. Section III.A.7. *Maintaining and Repairing Agricultural Machinery and Vehicles* discusses various methods of keeping an environmentally responsible farm vehicle.

- *Composting plant clippings*. Plant clippings can be composted, while tree clippings can be used as drying material to compost the plant clippings. Tree clippings can also be ground as mulch and reused in the fields or greenhouse. By placing wood waste under covered structures or tarps, operators can also reduce the decomposition and leaching from wood waste piles.[9]

[9] *Environmental Guidelines for Greenhouse Growers - Site Planning*, British Columbia Ministry of Agriculture and Food, 1998, http://www.agf.gov.bc.ca/resmgmt/fppa/pubs/environ/greenhse/grnhse.htm.

### III.B.7. Constructing and Maintaining Greenhouses

Greenhouse construction and design can influence how effectively horticulture crops grow, as well as the operation's ability to minimize environmental impacts. Greenhouse construction includes building the structure and ensuring that it meets the operational requirements of the horticulture operation.

Greenhouse maintenance involves maintaining the structural integrity as well as the appropriate climate conditions. Activities may include operating and maintaining boilers that provide heat during cold weather; operating fans to keep crops and workers cool during warm weather; and general maintenance of the greenhouse itself.

***Potential Pollution Outputs and Environmental Impacts***

The potential pollutant outputs from greenhouse construction include increased potential for storm water runoff during construction; air emissions from construction equipment; and construction wastes primarily consisting of packaging materials, steel or aluminum parts, and waste concrete. Boilers used for heating greenhouse can produce air emissions and potential spills of boiler chemicals can impact the environment.

***Pollution Prevention/Waste Minimization Opportunities***

Many pollution prevention opportunities begin at the design and construction stage. Pollution prevention opportunities in greenhouse design include:

- Locating storage facilities for fuel, wood waste, fertilizer, or pesticides far away and contained from any watercourse.
- Locating well water sites on the highest elevation on the property and as far as possible from areas where fertilizer, pesticides, and petroleum products are stored or handled.
- Designing the greenhouse so that it can accommodate efficient drip irrigation systems.
- Planning facilities that can separate and disinfect irrigation or wash water so that the water can be reused.
- Installing closed systems that minimize or prevent leaching from irrigation systems.

- Constructing foundations and floors that permit recovery of leachate, such as lined soil zones and concrete floors.

- Selecting efficient watering systems.

- For outdoor areas, using well-drained gravel keeping impervious pavement to a minimum.[10]

Implementing these activities in the design and construction stage helps facilitate their implementation throughout the production process.

### III.B.8. Packaging, Loading, and Transporting Products

Horticulture crops must be packaged, loaded, and transported by truck or rail to their destinations. Packaging materials may include plastic, burlap, or paper.

***Potential Pollution Outputs and Environmental Impacts***
The primary pollution outputs include damaged or dead plants and discarded packaging materials, all of which may be managed as solid waste. Hydraulic lifts or conveyors used in the loading process may leak oil, resulting in soil contamination.

***Pollution Prevention/Waste Minimization Opportunities***
Pollution prevention opportunities for packaging include reducing the volume of packaging used and recycling any waste packaging materials when possible. Pollution prevention ideas for reducing emissions from transport vehicles are similar to those discussed in Section III.A.7.

### III.B.9. Maintaining and Repairing Machinery and Vehicles at Greenhouses/Nurseries

Horticulture operations operate and maintain heavy equipment that is used for preparing soil, maintaining the crops, and transporting products for sale. Day-to-day maintenance and repair activities keep machinery and vehicles safe and reliable. Maintenance activities include oil and filter changes, battery replacement, and repairs including metal machining.

[10] *Environmental Guidelines for Greenhouse Growers - Site Planning*, British Columbia Ministry of Agriculture and Food, 1998, http://www.agf.gov.bc.ca/resmgmt/fppa/pubs/environ/greenhse/grnhse.htm.

***Potential Pollution Outputs and Environmental Impacts***

The wastes from maintenance and repair activities can include used oil, spent fluids, spent batteries, metal machining wastes, spent organic solvents, and tires. These wastes have the potential to be released to the environment if not handled properly, stored in secure areas with secondary containment, protected from exposure to weather, and properly disposed of. If released to the environment, the impact of these releases can be contamination of surface waters, groundwater, and soils, as well as toxic releases to the atmosphere. Groundwater pollution can also result from discharges of wastes to Class V wells.

***Pollution Prevention/Waste Minimization Opportunities***

Preventive maintenance programs can minimize waste generation, increase equipment life, and minimize the probability of significant impacts and accidents. Where the wastes cannot be eliminated, safe handling and recycling can minimize environmental impacts. Pollution prevention/waste minimization opportunities for these wastes are similar to those discussed previously in Section III.A.7.

### III.B.10. Fuel Use and Fueling Activities at Greenhouses/Nurseries

Fuel is used to operate agricultural machinery, equipment, and vehicles that are used for horticulture crop production, including preparing the site/soil, planting crops, applying nutrients and pesticides, irrigating, and post-harvesting activities. Agricultural machinery and vehicles are typically fueled using an aboveground fueling dispenser that is connected to an aboveground or underground fuel tank.

***Potential Pollution Outputs and Environmental Impacts***

Agricultural machinery and vehicles that use fuel most likely emit pollutants to the atmosphere. The activity of fueling itself can emit air pollutants, and spills of fuel can cause water, soil and groundwater contamination. Underground fueling systems that are not monitored or maintained properly can leak into the surrounding soils and eventually contaminate groundwater.

***Pollution Prevention/Waste Minimization Opportunities***

Properly maintaining fuel tanks, lines, and fueling systems can substantially reduce the probability of accidental fuel spills or leaks. All leaking pipe joints, nozzle connections, and any damage to the fueling hose (e.g., kinks, crushing, breaks in the carcass, bulges, blistering, soft spots at the coupling, deep cracks or cuts, spots wet with fuel, or excessive wear) should be fixed immediately to reduce the amount of pollution to the environment. Spill and overflow protection devices can be installed to prevent fuel spills and secondary containment can be used to contain spills or leaks. Additional pollution prevention techniques to prevent fuel spills and methods to more efficiently refuel are discussed in Section III.A.8.

## III.C. Forestry Production Industry: Operations, Impacts, and Pollution Prevention Opportunities

Nearly 500 million acres of forest land are managed for the production of timber in the United States. This section provides an overview of commonly employed operations and maintenance activities in the forestry industry. This discussion is not exhaustive; the operations and maintenance activities discussed are intended to represent the major sources of environmental impacts from forestry. It also presents an overview of pollution prevention and waste minimization opportunities within the industry.

### *Summary of General Potential Pollution Outputs and Environmental Impacts for the Forestry Production Industry*

EPA's National Summary of Water Quality Conditions (1998) lists silviculture nonpoint source pollution as contributing to 7 percent of impaired river miles, 7 percent of impaired acres of lakes, and 3 percent of impaired square miles of estuaries. Forestry activities can contribute to nonpoint source pollution and water quality degradation through erosion, removal of streamside vegetation, destruction of habitat, and the use of pesticides and nutrients, primarily commercial fertilizers. Habitat destruction can impact various animals, including endangered species such as the spotted owl. Eroded forest soils potentially are carried to surface waters where sedimentation occurs and stream life is negatively impacted. The removal of streamside vegetation increases the potential for erosion and also eliminates shading of the waterbody. Turbidity from erosion and reduced shade result in higher water temperatures and lower dissolved oxygen concentration. Pesticides and fertilizers can be carried in runoff to waterbodies affecting water quality.

### *Summary of General Pollution Prevention/Waste Minimization Opportunities for the Forestry Production Industry*

Best management practices applied to forestry operations can be classified as 1) prevention measures as part of planning, policy and management; and 2) reduction measures applied to the land as an integral part of the silvicultural activity. Prevention through management decision involves the incorporation of environmental protection into organizational policy and in the planning, design and scheduling of forestry activities. At this stage, location and design of logging access roads, intermediate activities, harvesting methods, and reforestation decisions should be made to prevent or minimize the aggravation of inherent pollution hazards.

The reduction measures to control erosion and sediment runoff generally utilize some physical, biological, or chemical method or technique. Reduction measures modify and reduce the unavoidable disturbances caused by an activity, for example, revegetation of cleared areas, mulching of roadcuts and fills, and removal of debris from watercourses. Reduction measures also include the construction of berms, rip-rapping, baffles, drop structures, catch basins, cross-drains, and slope stabilization on road sites. Because of the widespread nature of sediment runoff, erosion control measures must be a principal thrust of the water quality management program on each forestry management unit.

In areas where nutrients, pesticides, and other chemicals cause particular problems on surface waters or groundwater, further control measures may be necessary. These measures could relate to the application (timing methods and amount), utilization, and management of fertilizers, pesticides, and fire retardant chemicals. Particular attention should be taken to keep chemicals away from streams. Care must be exercised to ensure that thermal problems are not created in streams by excessive removal of shade canopy. Attention to proper forest management, engineering, and harvesting principles can substantially reduce pollution attributed to forestry.

The following considerations should be part of the pre-harvest planning stage: threatened and endangered species and sensitive habitats, wetland areas, streamside management area/width, cumulative effects analysis, timing of operation (i.e., to avoid moisture), and identification of landslide potential and other high risk areas.

### *Operations of the Forestry Production Industry*

This section describes the following forestry production activities:

- Road construction and use
- Timber harvesting
- Forest Regeneration
- Site preparation
- Prescribed burning
- Application of chemicals

Exhibit 22 presents raw material inputs and pollution outputs from each of these forestry production activities.

**Exhibit 22. Forestry Production Activities, Raw Material Inputs, and Pollution Outputs**

| Activity | Raw Material Input | Pollution Output |
|---|---|---|
| Road construction and use | S Fuel and oil used in construction equipment | S Sediment in runoff from soil erosion<br>S Air emissions |
| Timber harvesting | S Fuel and oil used in harvesting, chipping, loading, and hauling equipment | S Sediment and organic debris in runoff from soil erosion<br>S Thermal pollution<br>S On-site leaks (i.e., hydraulic fluid)<br>S Air emissions |
| Forest regeneration | S Fuel used in planting equipment<br>S Commercial fertilizers | S Sediment in runoff from soil erosion<br>S Nutrient in runoff from fertilizer application<br>S Air emissions |
| Site preparation | S Fuel and oil used in mechanical equipment<br>S Chemical herbicides | S Sediment in runoff from soil erosion<br>S Chemicals in runoff from herbicide application<br>S Air emissions |
| Prescribed burning | S Fuel to start fire | S Sediment in runoff from soil erosion<br>S Air emissions (smoke) |
| Application of chemicals | S Fertilizers<br>S Pesticides<br>S Water<br>S Fuel used in application equipment | S Chemical air emissions<br>S Runoff contaminated with chemicals |

## III.C.1. Road Construction and Use

Building the road system to allow for harvesting involves clearing the roadway of trees, grading soil, placing culverts for stream crossings, construction, and surfacing. Following road construction, the forest becomes accessible for the logger to fall the trees and transport them to a landing where they will then be loaded and transported to the mill.

There are several types of roads used in timber harvesting. The cheapest and easiest road is the skid trail which is usually nothing more than a dirt path used by the skidders to get the trees to the landing area. Skid trails must be located outside of the Streamside Management Zone (SMZ) and must use a bridge or culvert of acceptable design to cross perennial or intermittent streams. The road from the landing to the main road is usually better than a skid trail because it must support the trucks that haul the wood to the mill. Some wood product companies build roads designed to last for many years. However, these type of roads are too expensive for most landowners to construct.

Rolling dips, water bars, cross-drains, water turnouts, and culverts are used to control runoff and erosion, and allow vehicles to cross intermittent or perennial streams.

Abandonment of roads, watercourse crossings, and landings must be planned and conducted in a manner that provides for permanent maintenance-free drainage to soil resources; minimizes concentration of runoff, soil erosion, and slope instability; prevents unnecessary damage to soil resources; promotes regeneration and protects the quality and beneficial uses of water.

***Potential Pollution Outputs and Environmental Impacts***

The primary pollution outputs during road construction and use may include air emissions from road construction equipment and machinery used for harvesting and soil erosion. Roads are considered to be the major source of erosion from forested lands, contributing up to 90 percent of the total sediment production from forestry operations. Erosion potential from roads is accelerated by increasing slope gradients on cut-and-fill slopes, intercepting subsurface water flow, and concentrating overland flow on the road surface and in channels. Roads with steep gradients, deep cut-and-fill sections, poor drainage, erodible soils, and road-stream crossings contribute to most of this sediment load, with road-stream crossings being the most frequent sources of erosion and sediment. Soil loss tends to be greatest during and immediately after road construction because of the unstabilized road bed and disturbance by passage of heavy trucks and equipment.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention methods in road construction and use are designed to reduce erosion of soil and minimize delivery of sediment to surface waters. Proper road design and construction can prevent road fill and road backslope failure, which can result in mass movements and severe sedimentation. Proper road drainage prevents concentration of water on road surfaces, thereby preventing road saturation that can lead to rutting, road slumping, and channel washout. Proper road drainage during logging operations is especially important because that is the time when erosion is greatly accelerated by continuous road use.

Surface protection of the roadbed and cut-and-fill slopes can:

- Minimize soil losses during storms.
- Reduce frost heave erosion production.
- Restrain downslope movement of soil slumps.
- Minimize erosion from softened roadbeds.

Although there are many commonly practiced techniques to minimize erosion during the construction process, the most meaningful are related to how well the work is planned, scheduled, and controlled by the road builder and those responsible for determining that work satisfies design requirements and land management resource objectives. Most erosion from road construction occurs within a few years of disturbance. Therefore, erosion control practices that provide immediate results (such as mulching or hay bales) should be applied as soon as possible to minimize potential erosion.

Drainage of the road prism, road fills in stream channels, and road fills on steep slopes are the elements of greatest concern in road management. Roads used for active timber hauling usually require the most maintenance, and mainline roads typically require more maintenance than spur roads. Use of roads during wet or thaw periods can result in a badly rutted surface, impaired drainage, and excessive sediment leading to waterbodies. Inactive roads, not being used for timber hauling, are often overlooked and receive little maintenance.

The following pollution prevention practices can be used for road construction and use:

- Follow the design developed during preharvest planning to minimize erosion by properly timing and limiting ground disturbance operations.

- Design skid trail grades to be 15 percent or less. Do not locate and construct roads with fills on slopes greater than 60 percent.

- Avoid construction during fish egg incubation periods on streams with important spawning areas.

- Compact the road base at the proper moisture content, surfacing, and grading to give the designed road surface drainage shaping. Compact the fill to minimize erosion and ensure road stability.

- Use straw bales, straw mulch, grass-seeding, hydromulch, and other erosion control and revegetation techniques to complete the construction project. These methods are used to protect freshly disturbed soils until vegetation can be established.

- Use turnouts, wing ditches, and dips to disperse runoff and reduce road surface drainage from flowing directly into watercourses.

- Install surface drainage controls to remove storm water from the roadbed before the flow gains enough volume and velocity to erode the surface. Route discharge from drainage structures onto the forest floor so that water will disperse and infiltrate.

- Install appropriate sediment control structures to trap suspended sediment transported by runoff and prevent its discharge into the aquatic environment.

- Revegetate or stabilize disturbed areas, especially at stream crossings.

- Protect access points to the site that lead from a paved public right-of-way with stone, wood chips, corduroy logs, wooden mats, or other material to prevent soil or mud from being tracked onto the paved road.

- Construct bridges and install culverts during periods when streamflow is low. Excavation for a bridge or a large culvert should not be performed in flowing water. The water should be diverted around the work site during construction with a cofferdam or stream diversion.

- When soil moisture conditions are excessive, promptly suspend earthwork operations and take measures to weatherproof the partially completed work.

- Locate burn bays away from water and drainage courses.

- Maintain road surfaces by mowing, patching, or resurfacing as necessary. Clear road inlet and outlet ditches, catch basins, and culverts of obstructions. Blade and reshape the road surface to conserve existing surface material to allow normal surface runoff.

### III.C.2. Timber Harvesting

Timber harvesting includes felling trees, preparing them by limbing, cutting them into desired lengths, and moving them to a central, accessible location for transport out of the forested area. The timber is removed (skidded or yarded) to a temporary storage site or landing by one of three basic methods: tractor/skidder (on skid trails), groundlead or highlead cable, or various skyline cable methods. Balloons and helicopters are also used to a limited extent in some areas.

The most common methods of harvesting in the United States are clearcutting, shelterwood, selection, and partial cutting.

- *Clearcutting* is the harvesting of all trees in an area in one cut to create a new even-aged stand. The area harvested is large enough to create an open condition. Economically, clearcutting is most efficient for the logger because all trees are removed, and the feller and skidder operator are not continually confronted with avoiding trees spared from harvest. However, because of the large volumes of material per unit area removed during clearcutting, more trips are required by the skidder, causing the greatest disturbance to the forest litter and underlying forest soil of all harvesting systems.

- *In shelterwood harvesting*, a mature stand is removed in a series of cuts. Regeneration of a new stand occurs under the cover of a partial forest canopy. The final harvest cut removes the sheltering canopy and permits the new existing stand to develop in the open as an even-aged stand.

- *Selection harvesting* involves the removal of mature or immature trees either alone or in groups at somewhat regular time intervals from a forest stand. The objective of this harvesting system is the development and maintenance of an uneven-aged stand with trees of different ages or sizes intermingled singly or in groups. Individual (single) tree selection involves the removal of individual trees, while group selection may remove several adjacent trees covering a small fraction of an acre or larger numbers of trees covering areas as large as one or two acres. Group selection is distinguished from clearcutting in that the intent of group selection is ultimately to create a balance of age or size classes in a mosaic of small contiguous groups throughout the forest stand.

***Potential Pollution Outputs and Environmental Impacts***

The most detrimental effects of harvesting, which include soil disturbance, soil compaction, and direct disturbance of stream channels, are related to the movement of vehicles and machinery in the forest area, and the skidding and loading of trees or logs. These effects can be enhanced or minimized depending on logging operation planning, soil and cover type, slope, and the construction and use of haul roads, skid trails, and landings for access to and movement of logs. Thus, harvesting method used directly affects the amount of erosion, including the amount of sediment and organic debris that are transported into streams from the forest floor.

Harvesting can also increase stream water temperatures (i.e., thermal pollution) due to the removal of the canopy over streams, with the greatest potential impacts occurring in small streams. Temperature is a significant aspect of water quality. In some cases, it may strongly influence dissolved oxygen concentrations and bacterial populations in streams.

As with all harvesting methods, clearcutting can cause irreversible adverse impacts to the environment and can destroy an area's ecological integrity. These impacts include:

- The removal of forest canopy, which destroys the habitat for many rainforest-dependent insects and bacteria.

- The elimination of fish and wildlife species due to soil erosion and habitat loss.

- The destruction of buffer zones which reduce the severity of flooding by absorbing and holding water.

- The removal of forest carbon sinks, leading to global warming through the increased human-induced and natural carbon dioxide build-up in the atmosphere.

- The destruction of aesthetic values and recreational opportunities.

- Increased streamflow from removal of vegetation (resulting in reduction in transpiration and evaporation functions), fish passage barriers (i.e., improperly placed culverts), and cumulative effects within the watershed.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention methods in timber harvesting are designed to minimize sedimentation resulting from the siting and operation of timber harvesting, and to manage petroleum products properly. Logging practices that protect water quality and soil productivity can reduce total mileage of roads and skid trails, lower equipment maintenance costs, and provide better road protection and lower road maintenance. Careful logging can disturb soil surfaces as little as 8 percent, while careless logging practices can disturb soils as much as 40 percent. Higher bulk densities and lower porosity of skid road soils due to compaction by rubber-tired skidders result in reduced soil infiltration capacity and corresponding increases in runoff and erosion.

Locating landings for both groundskidding and cable yarding harvesting systems according to preharvest planning minimizes erosion and sediment delivery to surface waters. However, final siting of landings may need to be adjusted in the field based on site characteristics.

Landings and loading decks can become very compacted and puddled and are therefore a source of runoff and erosion. Practices that prevent or disperse runoff from these areas before the runoff reaches watercourses will minimize sediment delivery to surface waters. Also, any chemicals or petroleum products spilled in harvest areas can be highly mobile, adversely affecting the water quality of nearby surface waters. Appropriate spill prevention and containment procedures are therefore necessary to prevent petroleum products from entering surface waters. Designation of appropriate areas for petroleum storage will also minimize water quality impacts due to spills or leakage.

The following pollution prevention practices can be used during timber harvesting operations.

**Harvesting Practices**

- Harvest trees so that they fall away from watercourses, whenever possible, keeping logging debris from the channel, except where debris placement is specifically prescribed for fish or wildlife habitat.

- Any tree accidentally dropped in a waterway should be immediately removed.

**Practices for Landings**

- Landings should be no larger than necessary to safely and efficiently store logs and load trucks.

- The slope of landing fills should not exceed 40 percent, and woody or organic debris should not be incorporated into fills.

- If landings are to be used during wet periods, protect the surface with a suitable material such as wooden matting or gravel surfacing.

- Install drainage structures for the landings such as water bars, culverts, and ditches to avoid sedimentation. Disperse landing drainage over sideslopes. Provide filtration or settling if water is concentrated in a ditch.

- Upon completion of harvest, clean up landing, regrade, and revegetate.

- Locate landings for cable yarding where slope profiles provide favorable deflection conditions so that the yarding equipment used does not cause yarding corridor gouge or soil plowing, which concentrates drainage or causes slope instability.

**Groundskidding Practices**

T Skid uphill to log landings whenever possible. Skid with ends of logs raised to reduce rutting and gouging.

T Skid perpendicular to the slope (along the contour), and avoid skidding on slopes greater than 40 percent.

T Avoid skid trail layouts that concentrate runoff into draws, ephemeral drainages, or watercourses.

T Suspend groundskidding during wet periods, when excessive rutting and churning of the soil begins, or when runoff from skid trails is turbid and no longer infiltrates within a short distance from the skid trail. Further limitation of groundskidding of logs, or use of cable yarding, may be needed on slopes where there are sensitive soils and/or during wet periods.

T Retire skid trails by installing water bars or other erosion control and drainage devices, removing culverts, and revegetating.

**Cable Yarding Practices**

T Use cabling systems or other systems when groundskidding would expose excess mineral soil and induce erosion and sedimentation.

T Avoid cable yarding in or across watercourses.

T Yard logs uphill rather than downhill.

**Petroleum Management Practices**

T Service equipment where spilled fuel and oil cannot reach watercourses, and drain all petroleum products and radiator water into containers. Dispose of wastes and containers in accordance with proper waste disposal procedures. Waste oil, filters, grease cartridges, and other petroleum-contaminated materials should not be left as refuse in the forest.

- Take precautions to prevent leakage and spills. Fuel trucks and pickup-mounted fuel tanks must not have leaks.

- Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.

### III.C.3. Site Preparation

Site preparation is a management activity designed to increase productivity of a tract by controlling competing vegetation and debris that could slow seedling growth. It includes removal or deadening of unwanted vegetation prior to planting trees. Site preparation is accomplished by conducting prescribed burning, using herbicides, or disking (or otherwise altering) the soil.

***Potential Pollution Outputs and Environmental Impacts***
The pollution outputs may include air emissions from the machinery used, soil erosion during and after site preparation, and chemicals in runoff. Mechanical site preparation by large tractors that shear, disk, drum-chop, or root-rake a site may result in considerable soil disturbance over large areas and has a high potential to degrade water quality. Site preparation techniques that result in the removal of vegetation and litter cover, soil compaction, exposure or disturbance of the mineral soil, and increased storm flows due to decreased infiltration and percolation, can contribute to increases in stream sediment loads. However, erosion rates decrease over time as vegetative cover grows back. Prescribed burning and herbicides are other methods used to prepare sites that may also have potential negative effects on water quality.

***Pollution Prevention/Waste Minimization Opportunities***
The primary pollution prevention methods in site preparation are designed to minimize sediment runoff caused by soil-disturbing machinery and chemicals in runoff from herbicide applications.

Leaving the forest floor litter layer intact during site preparation operations for regeneration minimizes mineral soil disturbance and detachment, thereby minimizing erosion and sedimentation. Maintenance of an unbroken litter layer prevents raindrop detachment, maintains infiltration, and slows runoff. Mechanical site preparation can potentially impact water quality in areas that have steep slopes and erodible soils, and where the prepared site is located near a waterbody. Use of mechanical site preparation treatments that expose mineral soils on steep slopes can greatly increase erosion and landslide potential. Alternative methods, such as drum chopping, herbicide application, or prescribed burning, disturb the soil surface less than mechanical practices.

The pollution prevention practices that can be used during site preparation operations include:

- Mechanical site preparation should not be applied on slopes greater than 30 percent.
- Mechanical site preparation should not be conducted in streamside management areas. Also avoid mechanical site preparation operations during periods of saturated soil conditions that may cause rutting or accelerate soil erosion.
- Avoid working downhill or uphill. Always work along the contour. Site preparation often involves soil disturbance and can cause extensive erosion if done in a way that increases runoff potential. Leave strips of undisturbed soil to help catch any runoff on steep slopes.
- When moving slash and debris into rows, avoid pulling up topsoil with the debris. Many sites are degraded by the removal of topsoil. Make sure that the dozer operator monitors the operation closely and modifies his/her approach if soil begins to build up in the rows.
- Use haystack piling where possible instead of windrows.
- Locate windrows and piles away from drainages to prevent movement of materials during high-runoff conditions.
- Do not place slash in natural drainages, and remove any slash that accidentally enters drainages.
- Provide filter strips of sufficient width to protect drainages that do not have streamside management areas from sedimentation by the 10-year storm event.

### III.C.4. Forest Regeneration

Forest regeneration refers to the re-establishment of a forest cover on areas from which trees have been removed by some past occurrence, such as wildfire, timber harvesting, or temporary conversion to some other use than the growing of trees. When trees have been absent from a site for a number of years, regeneration must generally be achieved through seeding and planting. Regeneration of a harvested area includes both the natural regenerative process and man's activities in preparing the site and subsequent planting or seeding. The method of regeneration is determined largely by the silvical characteristics of the tree species involved, site limitations, economic considerations, and the land manager's desire for forest composition. In some plant communities, natural regeneration under any of the harvesting systems may also occur by regrowth from roots or stumps.

Preparation, as well as protection of an area, is sometimes needed for regrowth of a stand. Where site preparation for regrowth is needed, major activities may include (1) debris removal to reduce fire hazard and allow use of equipment for subsequent operations, (2) reduction or removal of brush or shrub cover and undesirable tree species, and (3) cultivation of the soils.

***Potential Pollution Outputs and Environmental Impacts***
The pollution outputs may include air emissions from machinery used for regeneration, sediment runoff caused by soil-disturbing machinery, and nutrient runoff from fertilizer applications.

When used indiscriminately for site preparation, fire, chemicals, and soil-disturbing machinery increase the potential for erosion and sedimentation and other pollution to occur. The impacts from sediment pollution as well as pollution from nutrients in runoff would be similar to those discussed in Sections III.A.1 and III.A.3, respectively. The time required before such pollution occurs is variable depending upon climatic factors, soil productivity and its influence on the rate of plant growth, the species planted or seeded, and the operational schedule. In some areas, the time span may be a single growing season, while in others, it may cover several years.

***Pollution Prevention/Waste Minimization Opportunities***
The primary pollution prevention methods in forest regeneration are designed to minimize sediment runoff caused by soil-disturbing machinery and nutrient runoff from fertilizer applications. Regeneration of harvested forest lands not only is important in terms of restocking a valuable resource, but also is important to provide

water quality protection from disturbed soils. Tree roots stabilize disturbed soils by holding the soil in place and aiding soil aggregation, decreasing slope failure potential. The presence of vegetation on disturbed soils also slows storm runoff, which in turn decreases erosion.

Mechanical planting using machines that scrape or plow the soil surface can produce erosion rills, increasing surface runoff and erosion. Natural regeneration, hand planting, and direct seeding minimize soil disturbance, especially on steep slopes with erodible soils. Fertilizers are occasionally introduced into forests to promote growth. Impacts of fertilizer application in forested areas could be significantly reduced by avoiding application techniques that could result in direct deposition into waterbodies and by maintaining a buffer area along the streambank.

The pollution prevention practices that can be used for forest regeneration operations include the following:

- Distribute seedlings evenly across the site.
- Order seedlings well in advance of planting time to ensure their availability.
- Hand plant highly erodible sites, steep slopes, and lands adjacent to stream channels.
- Operate planting machines along the contour to avoid ditch formation.
- Apply fertilizers during maximum plant uptake periods to minimize leaching. Base fertilizer type and application rate on soil and/or foliar analysis.
- For aerial spray applications of chemicals, maintain and mark a buffer area of at least 50 feet (or as specified on the label) around all watercourses and waterbodies to avoid drift or accidental application of chemicals directly to surface water.

### III.C.5. Prescribed Burning

Prescribed burning is used to prepare sites for regeneration, reduce uncontrolled fire hazard due to accumulation of litter and undergrowth, control low value hardwoods and unwanted shrub species, improve wildlife habitat, provide disease control, and improve accessibility. Fire is used deliberately under conditions where the area to be burned is predetermined and the intensity of fire is controlled.

***Potential Pollution Outputs and Environmental Impacts***

The pollution outputs may include air emissions (smoke) from the fire and soil erosion after the prescribed burning. Prescribed burning of slash can increase erosion by eliminating protective cover and altering soil properties. The degree of erosion following a prescribed burn depends on soil erodibility, slope, precipitation timing, precipitation volume and intensity, fire severity, cover remaining on the soil, and speed of revegetation. Burning may also increase storm runoff in areas where all vegetation is killed. Such increases are partially attributable to decreased evapotranspiration rates and reduced canopy interception of precipitation. Erosion resulting from prescribed burning is generally less than that resulting from roads and skid trails and from site preparation that causes intense soil disturbance. However, significant erosion can occur during prescribed burning if the slash being burned is collected or piled, causing soil to be moved and incorporated into the slash. The impacts of erosion and sediment runoff would be similar to those discussed in Section III.A.1.

Air emissions (smoke) from prescribed burning can have adverse effects on smoke sensitive areas such as airports, resorts or recreation areas, schools, hospitals, stock barns and holding pens, etc. Smoke can cause reduced visibility or smoke irritation to livestock and humans which may cause material loss and adverse health effects.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention methods in prescribed burning are designed to minimize sediment runoff caused by removal of surface cover and smoke from fire. Prescribed burning is usually the least expensive method of obtaining several specific goals in forest management. However, it should be planned well in advance to assure success. Aerial photographs can be very helpful. Areas that will benefit most from a prescribed burn should be selected and priorities should be set. High priority will probably be protection of unmerchantable size stands. Burning stands can facilitate regeneration and reduce site preparation costs.

If recommended burning techniques and weather conditions are followed, most prescribed burning will not create smoke problems.

First, land managers should determine if any smoke sensitive areas are near the burn. These are places where reduced visibility or smoke irritation to livestock and humans could cause material loss and adverse health effects. Examples of smoke sensitive areas are: airports, heavily traveled highways, communities, resorts or recreation areas, schools, hospitals, factories, stock barns and holding pens.

Prescribed burning should not be implemented if any sensitive area is within three fourths of a mile downwind of the burn. Different wind direction should be sought in these type of situations. Also, burning should not be conducted if the area already has air pollution or a visibility problem. Burning should be carried out only when the vertical dispersion is good (from fire weather forecast).

The pollution prevention practices that can be used during prescribed burning operations include the following:

- Carefully plan burning to adhere to weather, time of year, and fuel conditions that will help achieve the desired results and minimize impacts on water quality.
- Intense prescribed fire for site preparation should not be conducted in the streamside management areas.
- Piling and burning for slash removal purposes should not be conducted in the streamside management areas.
- Avoid construction of firelines in the streamside management areas.
- In prescriptions for burns, avoid conditions requiring extensive blading of firelines by heavy equipment.
- Use natural or in-place barriers (e.g., roads, streams, lakes, wetlands) as an acceptable way to minimize the need for fireline construction in situations where artificial construction of firelines will result in excessive erosion and sedimentation.
- Construct firelines in a manner that minimizes erosion and sedimentation and prevents runoff from directly entering watercourses.
- Revegetate firelines with adapted herbaceous species.

- T Execute the burn with a trained crew and avoid intense burning.

- T Avoid burning on steep slopes with high erosion hazard areas or highly erodible soils.

## III.C.6. Application of Chemicals

Chemicals are becoming more and more a part of forestry. Commercial fertilizers are applied to sizeable areas of forests as a means of stimulating growth of new plantations or established stands of trees. Herbicides are used widely for site preparation and stand improvement. Insecticides are used less extensively, but still comprise the major defense against damaging insects in forests.

***Potential Pollution Outputs and Environmental Impacts***

The potential outputs from application of forest chemicals may include runoff contaminated with chemicals associated with fertilizer and pesticide application, and chemical air emissions. Fertilizer loss may occur when fertilizers are improperly applied during the course of a silvicultural operation. Soluble forms of fertilizers may reach surface or groundwater through runoff, seepage, and/or percolation. Insoluble forms may be adsorbed on soil particles and reach surface water through erosion processes. Nutrients may also reach surface water by direct washoff of slash, debris, and recently applied fertilizer. Excessive nutrients can lead to imbalance in the natural life cycles of water bodies.

Pesticides, when applied during forest management operations, may be insoluble or soluble. Pesticides when applied aerially and in a broadcast manner may directly enter the surface waters. These chemicals then follow approximately the same pattern as nutrients. Pesticides, applied by the above methods, in a manner inconsistent with the label, may result in acute toxicity problems in water bodies.

***Pollution Prevention/Waste Minimization Opportunities***

The primary pollution prevention methods in operations associated with the application of chemicals are designed to minimize runoff contaminated with chemicals from fertilizer and pesticide application, and chemical air emissions. Nutrient pollution from fertilization on forest lands is controlled by using techniques which avoid direct application to surface waters. Also involved are the elimination of excessive applications, the selection of the proper fertilizer formulation, and the proper timing and method of application. The key factors in the selection of the type of fertilizer and the method of application which are most appropriate for pollution control are local soil nutrient deficiencies, the physical condition of the soil, the plant species requirements, cost factors, weather conditions, access, and topography.

The most common mechanism of pesticide pollution is direct transport by runoff. However, the mechanisms of leaching or subsurface flows may be important in areas of highly porous geologic materials, permeable soils, or high water tables. Practices that control erosion and runoff also reduce loss of applied pesticides. In addition to these practices, a number of other frequently used options exist. These options involve manipulation of the pesticide itself such as form, timing of application, etc. These can be used alone or in conjunction with the erosion and runoff control measures.

The pollution prevention practices that can be used during the application of forest chemicals include the following:

- For aerial spray applications, maintain and mark a buffer area of at least 50 feet around all watercourses and waterbodies to avoid drift or accidental application of chemicals directly to surface water. Also use nozzles and spray equipment that will reduce pesticide drift. With broadcast applications, use thickening agents, lower pressures, and larger nozzle sizes to keep the pesticide spray where it is applied.

- Apply pesticides and fertilizers during favorable weather conditions.

- Always use pesticides in accordance with label instructions, and adhere to all federal and state policies and regulations governing pesticide use. The pesticide label may specify: whether users must be trained and certified in the proper use of the pesticide; allowable use rates; safe handling, storage, and disposal requirements; and whether the pesticide can only be used under the provision of an approved Pesticide State Management Plan. Management measures and practices for pesticides should be consistent with and/or complement those in the approved Pesticide State Management Plans.

T Locate mixing and loading areas, and clean all mixing and loading equipment thoroughly after each use, in a location where pesticide residues will not enter streams or other waterbodies.

T Dispose of pesticide wastes and containers according to state and federal laws.

T Take precautions to prevent leaks and/or spills.

T Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.

T Apply slow-release fertilizers, when possible.

T Apply fertilizers during maximum plant uptake periods to minimize leaching.

T Base fertilizer type and application rate on soil and/or foliar analysis.

T Consider the use of pesticides as part of an overall program to control pest problems.

T Base selection of pesticide on site factors and pesticide characteristics.

T Check all application equipment carefully, particularly for leaking hoses and connections and plugged or worn nozzles. Calibrate spray equipment periodically to achieve uniform pesticide distribution and rate.